Bus Rapid Transit: Impacts on Travel Behavior in Bogotá

by

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B.S. Civil Engineering
Universidad de los Andes
Bogota, Colombia (1997)

Submitted to the Department of Urban Studies and Planning
in partial fulfillment of the requirements for the degrees of

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ABSTRACT

In the year 2000, the government of Bogotá, the capital of Colombia, undertook a major transformation of its public transport system. A Bus Rapid Transit (BRT) system named Transmilenio was implemented modifying the organizational scheme of service delivery, raising the level of service, and ultimately affecting travel behavior. This thesis studies the changes in travel behavior resulting from the introduction of the new mode and some of the impacts whereby induced. In particular it studies the competition between the traditional buses operating in mixed traffic and the BRT.

The main result is that traveling conditions have improved substantially which is reflected in the reduction of the burden associated with traveling. This is demonstrated by the lower value of time found for BRT in comparison to the existing mode. This thesis studies the consequences of these changes in terms of the future growth of the system and the fare for public transportation. In addition, it looks at the extent to which the new mode has modified the fundamental drivers of travel behavior in the city.

Thesis Supervisor: Ralph Gakenheimer
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1 Introduction

After 50 years regulating the public transportation system, the government of Bogotá carried out an ambitious plan modifying the organizational scheme of service delivery, raising the level of service, and ultimately affecting travel behavior. A new Bus Rapid Transit (BRT) network known as "Transmilenio" was implemented in three of the main city corridors. The Transportation Research Board's Transit Cooperative Research Program TCRP A-23 defines this technology as: [1]

"BRT is a flexible, rubber tired rapid transit mode that combines stations, vehicles, services, running way, and ITS elements into an integrated system with a strong positive image and identity. BRT applications are designed to be appropriate to the market they serve and their physical surroundings and can be incrementally implemented in a variety of environments. In brief, BRT is a permanently integrated system of facilities, services, and amenities that can collectively improve the speed, reliability, and identity of bus transit. In many respects, BRT is a rubber-tired light rail transit (LRT), but with greater operating flexibility and potentially lower capital and operating costs."

In addition to the operational characteristics, the implementation of BRT in Bogotá runs under privately contracted operations. The contracts do not include provisions for operational subsidies and the system's revenue is meant to cover all the operational costs. The new system competes with the existing service operated by privately owned and operated buses in mixed traffic. The two systems compete along three specific corridors, while in the remaining areas of the city; the buses operating in mixed traffic are the only public transport alternative. These new arrangement in the supply of public transport (e.g., infrastructure, operational and organizational) imply several transformations, among them:

[1] http://www4.nas.edu/trb/crp.nsf/All+Projects/TCRP+A-23

- Behavioral: Transmilenio now captures an important share of the transit market and presumably attracts some car users. It offers a higher level of reliability, information, and security in comparison to the old system.
- Economical: from a passenger-trip to a service-based revenue stream; from a business where the city government had no direct profits to one where it shares part of the revenue; from a production system where productivity was hardly an issue at the firm management level to one where it is paramount to its survival.
- Political: from a weak and unaccountable public agency to one highly regarded by the citizens, accountable to public scrutiny and government controls; from a dispersed, weak, and unaccountable private sector to a more cohesive and productive transportation industry; from a rival relation between the government and the private sector to one where trust, cooperation and collaboration are key.

Thus far, no study known to the author has analyzed in detail the relationships emerging from the changes in the supply of public transportation in Bogotá. Although it may be too early to be conclusive about the effects of the BRT, the majority of the studies have looked at its major impacts. For instance Hidalgo (2002) quantified some of the impacts at the aggregate level; he showed that pollution levels (SOx, NOx, an PM_{10}) measured in the vicinity of the main transit corridor have dropped, accidents and crime rates have declined, and travel time, for those using the new system, has been reduced by 32% while 83% of users declared that the main reason why the use the new system is time savings. He also emphasized that accessibility, consistency, and affordability are all important attributes. Montezuma (2002) looked at the system from an even wider perspective analyzing the transformations in the politics of the city, and how these changes have affected the mobility of the population. However, no study has looked in detail at the changes in travel behavior and how these might affect the future development of the system and the competing relationships between the public transportation modes. An ideal setting to conduct such a study would be a before-and-after evaluation that could link the transformations to changes in travel behavior. Unfortunately, a clear picture of both situations is not available and therefore I propose the analysis of the existing pieces of data to understand first, how travel behavior has changed and second, what are the implications of these modifications.

The introduction of the new transportation mode has consequences for automobile and transit users; while the former see how a neglected alternative (public transportation) raises its level of service and could become a viable possibility; the latter experience an increase and improvement of their options. Hence, Transmilenio entails a shift from a position of captivity to one of choice inasmuch as it constitutes, to a certain extent, a new alternative for all users.[2] This study, however, will exclusively look at the behavior of transit riders; the response of automobile drivers is out of the scope because of lack of data and the difficulties to isolate the effect of other significant factors.[3]

In particular I will examine, to what extent Transmilenio has improved the conditions of public transportation travelers by comparing several behavior indicators. Underlying such examination is the question of whether Transmilenio constitutes for the travelers a new transportation mode vis-à-vis the incumbent. The main benefit is represented by savings in travel time. In fact, these have been seen as the ultimate goal and reason of the transformation; as presented in Transmilenio (2000) these savings are instrumental in shrinking the gap between auto users and the majority of the population that use public transportation. In addition time savings free up time for productive activities like sharing time with family and friends, working, or studying. Savings in travel time constitutes the main gain but a further investigation of the way travelers value travel time provides additional and relevant insights that are worth studying. In this regard this thesis is meant to answer the following specific research questions:

1. What are the determinants of the choice between the two public transportation modes?
2. To what extent has Transmilenio modified travel behavior?
3. Are benefits and changes in travel behavior uniformly distributed among all public transportation users?
4. What are the challenges and opportunities that the new institutional arrangement will face given the new travel behavior?

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[2] Although existent and accessible, public transport was not an actual option for automobile drivers; in fact public transportation hardly attracted any non-captive riders.

[3] The installation of car restraining measures like "pico y placa" since 1998 modified the utilization of the private automobile irrespective of the introduction of the new mode.

Although pertinent for Bogotá and the development of its public transportation in the near future, this research is also relevant for cities looking at this experience as a way to solve different issues related to public transportation. Several cities in the developing world share many of the characteristics of Bogotá; in particular the captivity of public transportation riders, the high inequality between car users and transit users, and the incumbent character of small operators. The success of Transmilenio in addressing those issues has renewed the interest for Bus Rapid Transit, initially driven by the well-known case of Curitiba, Brazil and the lesser-known experience of other Brazilian cities and Quito in Ecuador. Transmilenio however, has surpassed the existing BRT systems in terms of its high capacity, thus questioning some of the figures typically calculated for bus systems and challenging more expensive alternatives like light and heavy rail systems (World Bank, 2002, Kuhn, 2002, Leriverend, 2002,) Despite the differences in the economic and political circumstances between cities in the developed world and Bogotá, academics and policy makers in the US and Europe have also considered this technology for future expansions of their respective transit systems (Federal Transit Administration [4], Jarzab et. al 2002, Polzin and Baltes, 2002, Carey G. 2002). Furthermore BRT systems have entered the sustainable transport discourse as an alternative to the growing motorization occurring in developing countries (Gakenheimer, 1999) and dominating the transportation panorama in most of the developed world.

This thesis is organized in five chapters:

a) The first chapter presents a history of public transportation in Bogotá starting with the description of the first formal public transportation service and ending with the current circumstances in the city. The chapter is descriptive in nature and its goals are to introduce the historical context where the changes are taken place and to identify the key actors in the transportation sector.
b) The second chapter provides the analytical framework for the study; it describes the general methodological approach and presents the techniques used to study travel

[4] http://www.fta.dot.gov/brt/index.html

behavior, namely: Structural Equations Modeling and Discrete Choice Models. It is meant to serve as a guide for understanding the following chapters rather than a comprehensive presentation of the techniques. In the text, there are references to relevant works in the respective topics.

c) The third chapter explores the fundamentals of travel behavior using Structural Equations Modeling and data from the1995 Household Survey conducted for the Transportation Master Plan for the City (JICA, 1996). Its objective is twofold; first, to uncover the main forces acting on the travelers; and second, to explore how the changes brought about by Transmilenio could have operated under such circumstances.

d) The fourth chapter analyzes the current situation from the standpoint of the public transportation rider vis-à-vis the competition between the two public transportation modes (i.e., the old traditional system and the new BRT). The objective is to understand how the introduction of Transmilenio has changed travel behavior and the new tensions emerging between the competing modes. The methodological approach for this analysis is Discrete Choice Modeling and the data come from a revealed preference survey conducted by de Department of Transportation Planning of Transmilenio S.A. in May of 2002.

e) The fifth chapter concludes the analysis with the main consequences emerging from the findings of the previous chapters. It summarizes the main findings and provides answers to the research questions aforementioned. In addition if provides policy recommendations and further research opportunities where appropriate.

2 The Historical Context of Public Transportation in Bogotá

2.1 Public vs. Private delivery of the service: competition on and off the road (1884 – 1951)

In 1884, the first public transportation service was delivered in Bogotá connecting over a 5 km horsecar line the old colonial center to the wealthiest north suburbs (Mejia, 1998) [5]. The service was contracted out to the American firm "The Bogotá Railway Company" and given the right to operate the cars and collect the revenue after a fixed annual payment to the city. The operator defined fares and frequencies, and decided vehicle characteristics, stops, and schedules. The government, on the other hand, was responsible for paving the roads and installing the fixed guideways. The first service extension came eight years later in 1892 when a second line connecting the city center with the main railway station was built.

The prosperity of the business, the fact that the government was receiving a meager fraction of the revenues while paying for the infrastructure, and the pressure from the community after years of bad service; all these factors invigorated by the conflict between the U.S. and Colombia over Panama, resulted in the nationalization of the American company in 1910 (Mejia, 1998, Castañeda, 1995). This year marked the start of the first public transportation company in Bogotá; for this purpose, the City Council was given the direction of the company and consequently routes, frequencies, line extensions and vehicle acquisition were decided in politicized meetings. In the same year, the first electrically powered streetcar started operations and by 1920 the trolley lines covered 27.1 kilometers. By 1922 the whole network was electrified resulting in better frequencies and schedule adherence while keeping the fare at the same level. The annual ridership increased from 8 million riders in 1921 to 12 million in 1922 (Castañeda, 1995). Simultaneously, the first buses were appearing along with an increasing number of automobiles; between 1922 and 1927 the former increased by 371% and the latter by 115% (Castañeda, 1995).

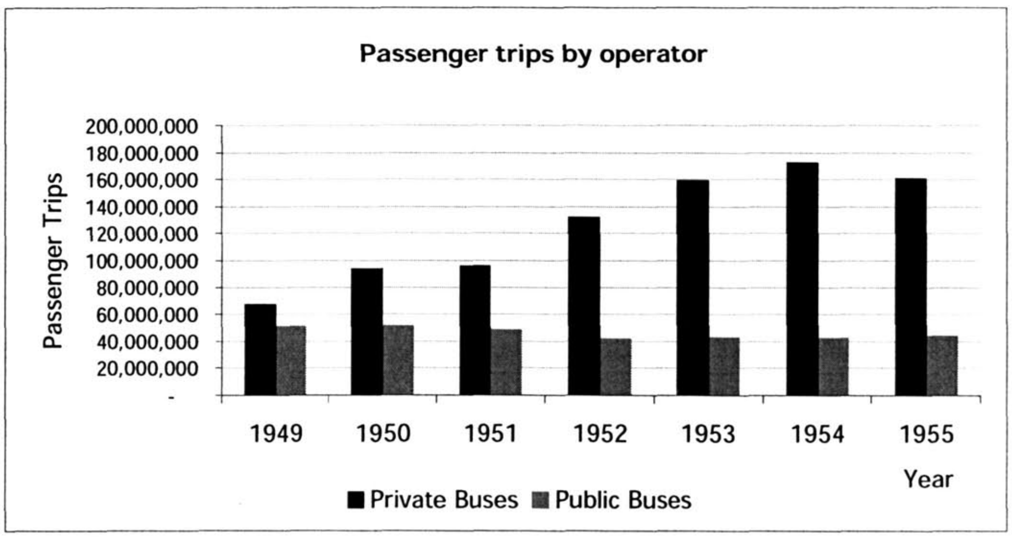
[5] Since 1870 omnibus services between Bogotá and the neighboring towns of Chapinero and Facatativa were provided, however those services can be categorized as inter city rather than "urban" services.

The increase in the number of buses has been associated with the growing number of "blue-collar" neighborhoods unserved by the trolley lines (Jimenez, 1985). The buses were initially organized in informal routes but by 1925 private entrepreneurs started asking for formal permissions. Although the City Council first denied these petitions claiming that the city revenue would be threatened, it eventually granted approval and the buses started running undermining the monopolistic position held by the trolley for 15 years. Responding to the competition, the City started a public bus company as a branch of the existing agency. The government not only competed with a new service, but through new regulation imposing fines to those buses circulating close, or on the same streets as the public services. Notwithstanding the government response, the private service grew resulting in a net drop of the trolley's market share in favor of the bus (in 1927 the trolley moved 80% of the daily trips but by 1939 only 50% (Castañeda, 1995)). On the road, the competition was in favor of the private buses because of the driver's profit oriented practices (driver's and owner's revenue depended on the number of passengers). On the other hand, the drivers of the public agency buses were securing a salary regardless of the number of passengers transported. Neither the public agency nor the private buses delivered a good service; the former suffered the effects of the competition and struggled to cope with higher production costs and lower revenues and the private buses were not interested in the level of service (they have a monopolistic position in may areas of the city), but arguably only in increasing their revenues while maintaining low costs. Castañeda (1995) reports many claims denouncing the bad level of service provided by the two modes.

Notwithstanding the private sector market competence on the road, the government still dominated most of the market through regulation and enforcement. Responding to that situation, representatives of the private operators eventually got elected to the City Council and presumably legislated in their favor. Tangible results emerged from this new situation; additional routes were authorized, roads were constructed on the outskirts of the city and the tax imposed on passenger trips, the only source of government income from the privately operated buses, was reduced (Castañeda, 1995). The presence of transportation sector representatives continued to be relevant in the city council until the end of the 1990s when the decentralization and democratization process over-rode their existing clientelistic behaviors, as suggested by Donovan (2002) in regards to public vendors similarly organized to public transport providers.

The 1940s saw the decline of the trolley and the public bus company. The turning point came in 1948 after the general chaos known as "El Bogotazo", when the mob, incited by the assassination of a popular political leader destroyed trolley lines, cars, and buses owned by the city. Three years later, in 1951 the trolley service disappeared and gave birth to an all-bus public agency with 124 buses operating in 10 routes. The publicly served network had to compete with 643 buses organized in 16 routes (Castañeda, 1995). The Public Agency operated large buses (55 seats) while the private strategy did it with smaller and faster vehicles of less than 35 seats. These smaller vehicles responded efficiently to the market desires, mainly to the needs of middle-class workers to commute faster to their jobs. In addition, small vehicles were cheaper and easier to acquire by a growing number of bus owners. This new picture of the transportation system is represented by the development of market share during the first five years of the 1950s as shown in Figure 2-1.

Figure 2-1 Annual passenger trips by company type



Source: Data taken from Castañeda W. (1995) Transporte Público Regulación y Estado en Bogotá 1882-1980. CEAM, Universidad Nacional de Colombia, IDCT, Bogotá.

2.2 The public sector from competitor to regulator (1951 – 2000)

The first years of the 1950s were a clear picture of the development of the public transportation market after the trolley company was terminated and the competition between the public and private buses began. By the 1980s, the market share of the public company was roughly 1% (Mohan, 1994) and in 1992 the public company eventually went out of business. By contrast, the private provision of public transportation grew rapidly and strongly. In this section I will describe some of the factors explaining this process and why several attempts by the city to regain power and reform the sector failed.

2.2.1 Urbanization

The urbanization process spurred by a growing population demanding housing and transportation services is the first factor explaining the growth of public transportation in the city. Table 2-1 registers the population, city area, and the corresponding annual growth rates for selected years from 1951 to 1998.

Table 2-1 Population and Area Growth in Bogotá between 1951 and 1998

Year	Population	Area	Annual Equivalent Growth Rate	
		(Hectares)	Population	Area
1951 (i)	658,236	NA	-	-
1958 (ii)	1,130,000	8,084	7.98 %	-
1964 (i)	1,730,000	14,615	7.36 %	10.37 %
1973(i)	2,877,000	30,423	5.81 %	8.49 %
1978(i)	3,500,000	30,866	4.00 %	0.30 %
1985(ii)	3,937,014	31,052	1.70 %	0.08 %
1993 (iii)	4,922,825	NA	2.84 %	-
1998 (iv)	6,319,396	NA	5.11 %	-

(i) Mohan R. (1994), Understanding the Developing Metropolis, Lessons from the City Study of Bogotá and Cali, Colombia. World Bank, Oxford University Press, New York.

(ii) Montezuma (1996), El transporte Urbano de Pasajeros en Santafe de Bogotá, una compleja estructura donde la responsabilidad final es asumida por los propietarios y por los conductores, in Montezuma R., Merlín P., Lablee J.C., Villalante M. (eds) El Transporte Urbano: Un desafío para el Próximo Milenio. CEJA, Bogotá.

(iii) Departamento Administrativo Nacional de Estadísticas, Censo 1993

(iv) Departamento Administrativo de Planeación Distrital, Projected 1998.

Between 1951 and 1998 the population experienced almost a ten-fold increase. This growth developed in phases; the rapid population growth of the 1950s and 1960s is usually associated with migrants from the countryside escaping from the violence in rural areas. During the same decades the road network was extended and affordable housing projects were developed. The 1980s were characterized by lower growth rates but the 1990s experienced considerably higher growth rates. From the mid 1990s to date, a migration phenomenon similar to the one of the 1950s is occurring as the violence has risen again in the countryside displacing a large number of people to urban areas.

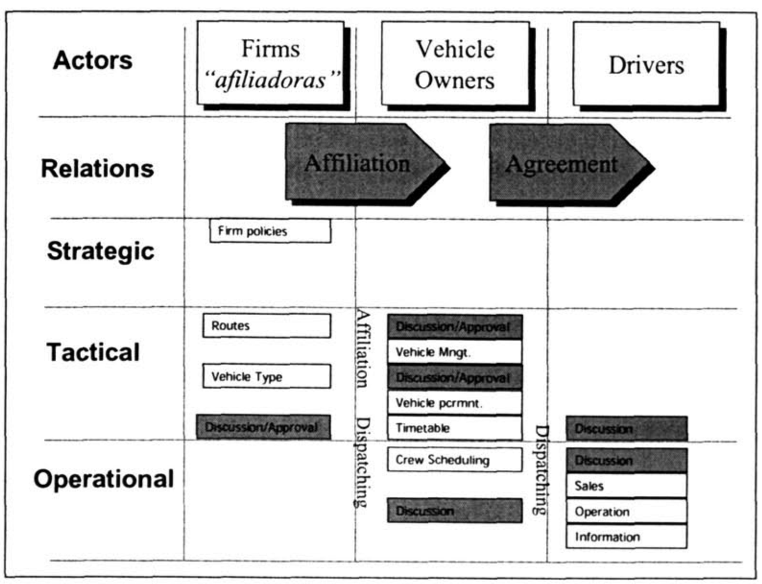
Some authors (Montezuma, 1996) suggest that during the first 30 years of the second half of the century, the housing and the transportation sectors grew hand-in-hand, in particular concerning irregular housing developments. Those settlements were often served by public transportation before they could access other services like water, electricity, or sanitation. Transportation was delivered by small operators presumably associated with the developers; not surprisingly several neighborhoods in the city bear the name of transportation companies. The outcome of the urbanization process generated a demand for a larger bus network and defined the geography of the trips; from the poor and middle-class neighborhoods located at the outskirts of the city where cheaper land was available or where squatting occurred, to the center where the jobs and services were concentrated. The higher income levels although moved northwards remain close to the Center Business District.

Arguably, the exclusive provision of public transportation by the government would not have sufficed to cope with the demand growth of the second half of the 20th century. Experiences from cities in other developing countries show that formally, through contracts, or informally, the private sector has replaced the state as the main provider of public transportation (Gwilliam 1997). The first section of this chapter showed that the government did not provide adequate service over the first half thereby creating the opportunity for private initiatives responding to the unmet demands. The next section describes how these opportunities were materialized by a growing industry.

2.2.2 Firm Evolution

Although legally constituted as firms, the providers of public transportation from its inception lacked many characteristics of what is conventionally consider a transportation company. That is, firms were not controlling, either by direct production or contracted services, the unified ownership, operation, and maintenance of equipment, facilities and services (Salvucci et. al, 1997). The resulting structure emerged from the firm's origins; some authors, like Castañeda (1995), argue that the cooperative structure promoted in the mid 1930s, lowered capital investments through shared vehicle ownership and tax benefits. This entry scheme defined the firm as an intermediary between the government and the bus owners, and not as a transportation firm insofar as the firms only functioned to gain approval for the operation of the vehicles and routes but not to produce transportation output. This structure produced a business structure as depicted in Figure 2-2. [6]

Figure 2-2 Organizational structure of transportation firms in Bogotá



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[6] The model used to describe organizational schemes in public transport is taken from VAN DE VELDE D.M. (1999) Organisational forms and entrepreneurship in public transport Part 1: classifying organisational froms. Transport Policy 6 (1999) pp. 147-157. The shaded boxes are activities that are carried out jointly by at least two parties. The vertical text is the process through this joint procces is carried out.

Three actors comprise the prevailing organizational structure; the *"afiliadoras"*, the bus owners, and the bus drivers. In the first level, the "*afiliadoras*", are intermediaries between the government and the bus owners. Its chief role is the affiliation of vehicles and their function is to gain governmental approval for routes and guarantee a level of service delivered by a fixed number of vehicles. Notwithstanding the agreement, no contract between the government and the firms is involved. To maximize its profit, "*afilidoras*" had to affiliate bus-owners into the company and assure the approval for as many routes as possible. The affiliation usually involves purchasing one of the fixed number of slots approved by the authority *("cupos")* (1995 US$ 2,300 to 4,600), an affiliation fee (1995 US$100 to 600), and a monthly fee (1995 US$ 35 to 50)[7], and entailed authorization to operate on a certain route. Hence, the firms constantly sought for routes and vehicles; in addition, the longer the route, the greater the number of vehicles that could be requested to the authority. As an example, Sagaris (2001) recently interviewed the director of one the largest firms in the city and reported that the firm was a 40 years old family business running 1200 buses, 100 owned by the family and the remaining 1100 by affiliates.

In the second level, the bus owners, maximizes its profits by minimizing the variable cost and maximizing their revenue by means of passenger trips served. The common strategy in this tier is to cut on vehicle maintenance and labor costs. Typically, all the revenue is collected by the owner and later shared with the driver. At the end of the month, the corresponding affiliation fees are paid to the upper level.

The third level, the drivers, is comprised by an undetermined number of individuals with the daily responsibility of delivering the service. Their income comes directly from the production of transportation output through one of many documented types of agreement between owners and drivers (Montezuma 1996, Lanzetta de Pardo et. al, 1988, Mohan, 1994) whereby to maximize the drivers' profit they have to maximize the number of passenger trips served. Historically, there has been an unlimited supply of labor for drivers hindering the possibility of developing a stronger group and leveraging their position in the business.

[7] All numbers are from Montezuma R., (1996) El transporte Urbano de Pasajeros en Santafe de Bogotá, una compleja estructura donde la responsabilidad final es asumida por los propieatarios y por los conductores, in Montezuma R., Merlín P., Lablec J.C., Villalante M. (eds) El Transporte Urbano: Un desafío para el Próximo Milenio. CEJA, Bogotá.

On the other hand, almost all drivers want to evolve into bus owners, in fact one could argue that the ladder is clearly established and many drivers have succeeded in becoming the chiefs of the "afiliadoras" while owning several buses. In the late 1980's Lanzetta de Pardo et. al (1988) described the socio economic characteristics of drivers and found that those owning a vehicle have spent several years as paid operators. More recently, Montezuma (1996) encountered the same kind of ownership path in the mid 1990s; he calculated an average of nine years of savings from wages as a driver to be able to purchase a vehicle. Both studies, in different points in time, identified some of the most common practices carried out by the actors in the business. Small owner-operators choose not to affiliate to social security, avoid declaring earnings to city officials, and circumvent regulations in order to maximize profits. Typically, workers find ways to increase their low wages by under-the-table practices such as modifying the number of passengers transported by shift. Nevertheless, the transportation industry has generated a large number of jobs especially for low skilled labor. Montezuma (1996) and Mohan (1994) reported that despite the harsh working conditions, driver's wages were higher than the minimum wage.

The abovementioned conditions created the incentives for people to enter the business, and partially explain the growth in the size of the sector. The direct result is a dispersed market with many firms (55), vehicles (22,000), vehicle owners (23,000), and drivers. The data on the number of buses and routes in the city is not very reliable and the official records are poorly kept. Table 2-2 shows the growth of the sector from 1951 to the year 1999.

To study the degree of dispersion within the industry, Gini coefficients were calculated to evaluate bus-ownership and route-authorization distribution among the firms as of 1999. For bus-ownership the Gini coefficient was 0.437 and the ratio of the biggest (8.93%) to the smallest (0.04%) firm was 207. Notwithstanding this seemingly high value, the sector enjoys a fairly good distribution of vehicles among firms. In the case of route-authorization, the Gini coefficient was 0.441 and the ratio of the biggest (10.02%) to the smallest (0.16%) was 63. It is not surprising to found that the two biggest firms by number of vehicles coincide with the two biggest firms by number of routes. The two distributions are very similar; in fact the two measures of concentration are highly correlated (0.899).

Table 2-2 Growth of Public Transportation Fleet.

Year	Firms	Vehicles	Annual Compound Growth Rate Vehicles
1951	NA	767	
1972	NA	6,115	10.39 %
1973	NA	6,467	5.76 %
1974	NA	6,896	6.63 %
1975	NA	7,469	8.31 %
1976	NA	8,158	9.22 %
1977	NA	8,653	6.07 %
1978	NA	9,125	5.45 %
1979	NA	9,914	8.65 %
1980	39 (i)	10,636	7.28 %
1981	NA	11,414	7.31 %
1982	NA	12,102	6.03 %
1983	NA	12,522	3.47 %
1984	NA	12,942	3.35 %
1985	NA	13,046	0.80 %
1986	NA	13,049	0.02 %
1995	53 (ii)	21,872 (ii)	5.91 %
1999	55 (iii)	22,031 (iii)	0.18 %

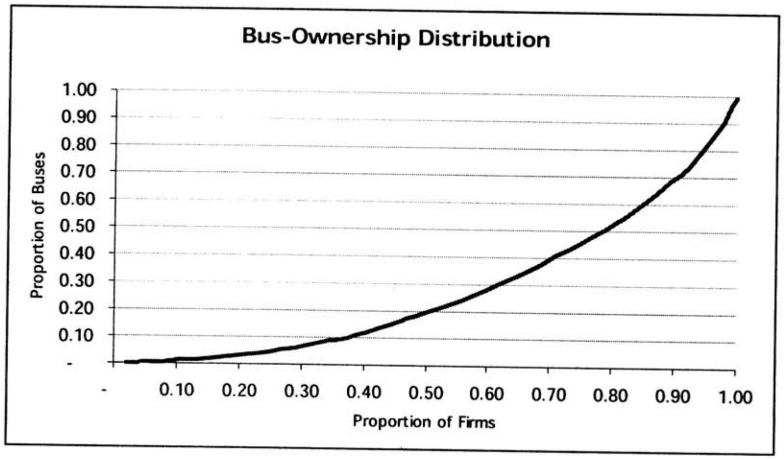
Source: Castañeda W. (1995) Transporte Público Regulación y Estado en Bogotá 1882-1980. CEAM, Universidad Nacional de Colombia, IDCT, Bogotá. Except:

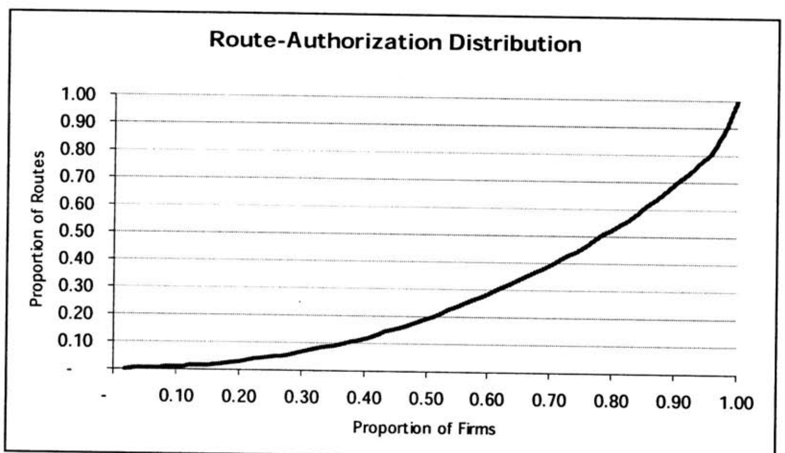
(i) Mohan R. (1994), Understanding the Developing Metropolis, Lessons from the City Study of Bogotá and Cali, Colombia. World Bank, Oxford University Press, New York.

(ii) Montezuma R., (1996) El transporte Urbano de Pasajeros en Santafe de Bogotá, una compleja estructura donde la responsabilidad final es asumida por los propieatarios y por los conductores, in Montezuma R., Merlín P., Lablec J.C., Villalante M. (eds) El Transporte Urbano: Un desafío para el Próximo Milenio. CEJA, Bogotá.

(iii) Secretaría de Tránsito y Transporte de Bogotá 1999.

Figure 2-3 Distribution of Buses and Routes per firm *"afiliadora"*





Source: Own calculations over data from ***Secretaría de Tránsito y Transporte***, 1999.

The large and dispersed sector influenced the level of service in contradictory ways. On the one hand, coverage and frequency were good attributes of the service but travel time, reliability, security, and comfort were attributes where the system failed to provide a good service. In addition, it produced congestion, unsafe conditions on the roads, and pollution due to the low maintenance of the engines and elevated age of the vehicles.

Thus far, only the service being delivered under legal conditions has been described, in addition, a number of vehicles deliver service in several areas of the city without any affiliation to authorized firms or approval from the government. The number of this type of vehicles often referred as illegal, informal, or "pirates", is only speculative; according to a union of small public transportation providers the number is 20,000 vehicles. [8]Although their influence is relevant for some areas of the city they will remain out of the scope of this thesis due to lack of reliable information or documentation. However, their existence is significant inasmuch as it shows that even with a very large number of buses and routes, some demands are still unmet.

2.2.3 The Role of the Government

The third factor is the role of the government vis-à-vis the demands resulting from rapid urbanization and a strong but rather scattered transportation industry. After 1951 the city's involvement in transportation started to shift from regulator/competitor to exclusively regulator. The shift was completed by 1992 when the publicly owned company stopped operations after many years of a service that capture less than 1% of the market. During those 40 years, the government sought to improve the service by regulating firm structure, setting standards for the operation of vehicles, and later by creating barriers for entry of new firms and new vehicles Those efforts were mostly futile, the main reason being the character of the firms; these were never strong entities and the atomization of the sector hampered the success of the government attempts to gain control. By the early stages of formation of the industry, the two most frequently mentioned obstacles to improve the service, namely, the lack of transportation firms and the semi-formality of the business were already identified (Castañeda, 1995). Yet fifty years later, those two factors are still seen as the main obstacle faced by the government to improve level of service.

The first attempt to modify the business structure during the second half of the century came with the enactment of the Law 15 of 1959. Earlier, that same year the operators arguing that the farebox recovery did not cover their operational costs asked for an increase, a measure that was heavily opposed by the population. In response, the government opted for an operational subsidy through the enactment of the law giving power to the national government to intervene in local matters concerning the provision of public transportation. The law allowed the national government to define the organizational structure of the firms, minimum capital investments, and strict regulation concerning wages

[8] El Tiempo, 11/03/ 2001, "Pico y Placa seguirá en discusión"

and benefits. Notwithstanding these objectives, the law's only tangible result was the creation of the subsidy because the requirements and standards of service never materialized. A flat monthly subsidy was paid by the national government to the firms, which in turn distributed among their affiliates.

Some authors (Pachón, 1981, Mohan 1994) describing the situation in the late 1970s and early 1980s, argued that the subsidy had a net positive effect because the city enjoyed a high level of transportation at low social and private costs and allowed the poor to have better access to transportation. Another relevant effect of the subsidy was to foster investments in newer vehicles by paying higher subsidies to the owners of the newer vehicles. They also analyzed the effect of the subsidy over the real service provided, encountering that it was not significant, by contrast others (Acevedo, 1988) found that the subsidy indeed created the incentives for reducing the service, therefore cutting costs while maintaining a fixed revenue through the subsidy. The main argument is that neither the firms nor the government had effective controls for monitoring bus operations. Whatever the case, Castañeda (1995) points out that by 1983, the subsidy became a major burden to the national finance and consequently started to be dismantlement by creating a level of service known as ***"Transporte Sin Subsidio"***, buses operating without the subsidy but with the same fare as the subsided vehicles. Yet, these buses did not comprise the first service operating without subsidies; earlier in 1975 the government authorized a new level of service called ***"buseta"*** charging a fare 2.5 times the bus fare. The service was intended to serve a segment of the market with higher incomes by offering buses of lower capacity (28 seats) and assuring that a seat was always available (i.e. standees were not allowed). These minibuses turned out to be very profitable and thereby this level of service witnessed an extraordinary growth during the 1970s. Later in the 1980s and the 1990s the government created new level of services with differentiated fares and by 1998 the supply of transportation was comprised by approximately 10 different vehicle and service types, from minibuses of 13 seats to large buses that could carry 100 passengers. This strategy, although adequate in terms of price segmentation, exacerbated the atomization of the sector by including yet another factor of division; that is the vehicle-service type.

The other dimension where the role of the government can be analyzed is in the planning process for a mass transportation system. The first attempt dates back to 1947, in total there have been more than 10 plans to implement a heavy rail solution to the transportation demand, the last one being carried out in 1997. Ardila (2001) argues that the main reasons for the failure of those plans were the lack of political and financial realism, lack of organizational capacity to carry on the plan, and the failure to understand that implementation was the driver of the plan.

Despite the failure to provide a rail-based solution, the city, inspired by the experience of Curitiba and other Brazilian cities, developed between 1988 and 1992 an exclusive bus lane on its main transit corridor "Avenida Troncal Caracas" (Acevedo, 1996, Ardila 2001). Only the existing larger buses operated in this corridor while smaller buses were relocated to parallel roads. In total, the busway extended for 16 kilometers and accommodated more than 200 bus routes (Rodríguez and Ardila, 2002). This trunk corridor became the core of the transportation system recording passenger flows per hour per direction of 36,000 in the year 1999 (Steer Davies Gleave, 1999, Ardila and Rodríguez, 2000) and offering a considerably high speed of 24 km/hr (15 mph) in comparison to the city average of 9km/hr (5.6 mph) (Rodríguez and Ardila, 2002). Nonetheless, the service was regarded as poor and the corridor became one of the most hated, unsafe, polluted, and congested venues of the city. A previous work by Ardila and Rodriguez (2000) studies the duality between high passenger throughput and poor service. Negative impacts over the vicinity of the corridor were strong; real estate prices plummeted, crime rates were high, and the surroundings were in an overall decline.

It is often argued by some of the Brazilian and Colombian engineers that participated in the planning process of the "Troncal Caracas" that it did not reach all its goals because the homework was never fully finished. The plans for the construction of terminals and the development of a feeder network never came to completion. In addition, adherence to the operational scheme never materialized because the monetary incentives of the business were not modified; still the driver's revenue came from the number of passenger-trip served creating the incentive to pick up passengers wherever they were demanded and not where it was established by the designs[9]. Rodríguez and Ardila (2002) reinforcing this opinion, state that the inadequate institutional arrangement determined by large the operation of the vehicles in the trunk corridor and thereby the level of service. From 1992 to 1998, plans to

[9] Between 1999 and 2002, the author conducted interviews with engineers and planners that took part of the design of Troncal Caracas.

improve and expand the busway system failed due to the same reasons that Ardila (2002) argued in regards to the heavy rail plans. Notwithstanding its negative connotations, the first exclusive bus lane experience was worth in at least two ways; first, it prioritized road space for the buses producing higher speeds and passenger throughputs; and second, it provided knowledge about the drawbacks and backlashes of a poorly managed busway.

By the end of the 1990s the public transportation system reached a situation characterized by a weak government in transportation matters, a disperse industry with serious financial issues, and a large number of captive riders subject to a poor level of service. Under these circumstances, Enrique Peñalosa started his tenure as Bogotá's Mayor having amongst his goals a total revamp of the mobility policy with Transmilenio as its flagship. Transmilenio was the cornerstone of a policy that conveyed to the population that a mobility strategy based on the private automobile was not sustainable. The policy aimed at building a consensus around the need for the recuperation of public spaces, a restrain to the private automobile utilization, the improvement of parks, construction of bicycle paths, and the redistribution of road space such as to prioritize public and non-motorized modes of transportation.

2.3 Transmilenio

Transmilenio is a Bus Rapid Transit network that builds on the experiences of other busways in Latin America (e.g., Curitiba, Sao Paulo, Quito) although designed to manage substantially higher passenger flows. Curitiba busway's highest peak-hour, peak-direction, demand is approximately 11,000 (Levinson et. al, 2002) while Transmilenio is designed for 35,000 passengers per hour per direction (Steer Davies Gleave, 1999) and is currently managing demands of around 25,000 (Levinson et. al, 2002). The ultimate objective of the new system is to raise the level of service of transit as an instrument to improve the sustainability and productivity of the city. The underlying reason is that time savings for transit users (the majority of the population), reduce the levels of inequality between those that own vehicles and those who do not, in addition it frees up time for productive activities like studies, work, or family time (Transmilenio, 2000).

Its creation entailed a new transit agency, the construction of new infrastructure, and the development of a business structure whereby the existing providers of public transportation could still operate but under a different organizational scheme. The new public agency, called Transmilenio S.A., is now in charge of planning and administering the system. The new construction was publicly financed and consisted of exclusive bus lanes, bus stations, bus terminals, and bus depots. The main change however, occurred in the economic incentives of the business; while in the past, the operator's revenue came directly from the number of passengers transported; now it comes from a fixed cost per kilometer subject to constraints dictated by level of service premises. The providers are selected after a tendering process that evaluates their experience, financial capabilities, and price offer. Currently most of the providers correspond to consortiums formed by the "afiliadoras". The revenue is shared between the agency, the transportation providers, a contractor that takes care of the fare collection system, a fiduciary that makes sure that the revenue is properly distributed, and other contractors that maintain and clean the facilities. The system is operational on its first phase consisting of: [10]

- 39 Kilometers of Exclusive Bus Lanes
- 57 Stations
- 4 Bus Terminals
- 4 Bus Depots
- 470 Trunk Vehicles
- 12 Trunk Routes
- 241 Feeder Vehicles
- 39 Feeder Buses

As argued by Rodríguez and Ardila (2002), two characteristics of the system implementation makes it very attractive as a model to replicate, first its piecewise development allows operations to start even when the whole system is not fully completed; and, second its low cost in comparison to mass transportation solutions based on rail, makes it affordable for many cities. Construction costs are summarized in Table 2-3.

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[10] http://transmilenio.gov.co/Transmilenio.htm Accessed on November 25th 2002.

Table 2-3 Cost of construction of Transmilenio – First Phase

Element	Total Cost (2000 US$ Millions)	Cost per Kilometer of Exclusive Bus Lane (2000 US$ Millions)
Trunk Corridors	94.7	2.5
Bus Stations	29.2	0.8
Bus Terminals	14.9	0.4
Access to Stations	16.1	0.4
Bus Depots	15.2	0.4
Operations Control Center	4.3	0.1
Others	25.7	0.7
Total	198.8	5.3

Source: El Sistema de Transporte Masivo de Bogotá. Subgerencia General de Transmilenio. Presented at the First International Seminar on Urban Transportation and Transmilenio, November 14, 2001.

After almost two years of operation the system carries on average 770,000 passenger-trips per weekday, of those approximately 400,000 make use of the integrated feeder-trunk system.[11] The remaining demand for public transport (approximately 8 million daily trips) is still being served by the traditional system with buses operating in mixed traffic. This system did not experience any transformation on its business or operational practices as a result of Transmilenio. The changes however, came in two ways: First, the route network was modified, as Transmilenio's exclusive bus lanes required the relocation and/or cancellation of some routes. Second, the demand for the old system dropped and hence its revenue per vehicle. Despite the requirement for Transmilenio providers to purchase and scrap buses from the traditional system, no substantial reduction of the fleet has been realized; this process is occurring but a very slow pace. The abundant supply of transportation in other corridors unserved by the BRT has caused congestion. There is no official measurement of these changes, but the union of small providers of public transportation argues that in parallel corridors there has been an increase in the travel time of around 10%.[12]

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[11] http://transmilenio.gov.co/Transmilenio.htm Accessed on November 25th 2002

[12] Other Corridors like Cra. 7 and Cra. 13. El Tiempo, 11/03/ 2001, "Pico y Placa seguirá en discusión"

2.4 Conclusion

In Bogotá, the development of the urban transportation over the 20th century resulted in a wide public transportation network serving a large, but mostly captive, demand. By the 1980s, researchers like Mohan (1994) showed that the provision of public transport was efficient insofar as it offered a good service while keeping the social and private costs low. However, he pointed out that congestion was already affecting the level of service. Fifteen years later the situation was quite different; the number of vehicles experienced a two-fold increase and the congestion spread over the main corridors. In the year 2000, Transmilenio a new Bus Rapid Transit system, transformed the provision of public transportation creating a new organizational structure. It rests on a transformation of the operational scheme, and productivity of the system resulting in a better level of service for the riders. The improved service is meant to reduce the levels of inequalities in access and use of modes of transportation and to free time that can be put into productive activities.

This new operational and organizational scheme coexists with the traditional mode operating in mixed traffic, and still capturing approximately 90% of the daily demand. Competition and cooperation between the two systems is likely to determine the way public transportation will develop in the near future. Moreover, when many of the "afiliadoras" (e.g., previous transportation providers) have evolved into the providers of Transmilenio; that is, many of these firms maintain economic interests in both sectors.

This chapter has described the three main actors in the public transportation system, namely the riders, the private providers of the service, and the government. The context provided so far is instrumental in understanding the findings of following chapters. They look at how the relationships between the actors have changed as a result of the transformation of the status quo via raising the level of service and modifying the fundamentals of service provision.

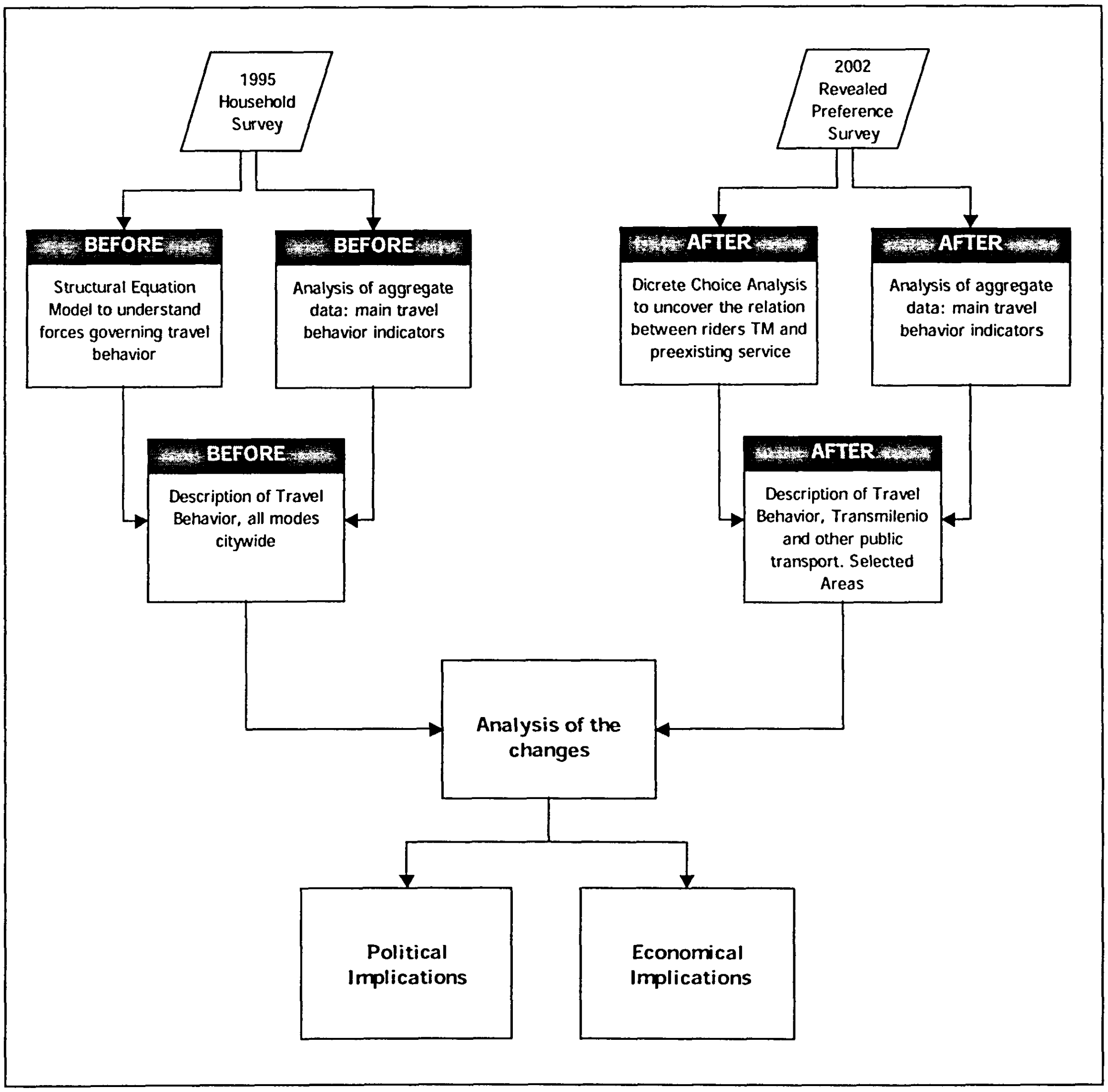
3 Analytical Framework

The objective of this study is to analyze the consequences of the changes in travel behavior resulting from the introduction of a new public transportation mode (Transmilenio) in a city in the developing world (Bogotá). The analytical approach can be seen as a three-step process whereby I first analyze the prevailing travel patterns before the transformations, then I study a partial picture of the current conditions quantifying some of the changes, and describing the competition between the existing public transportation modes; and finally, using travel behavior indicators I present the main consequences of the process of change and issue policy recommendations when appropriate. Figure 3-1 presents the approach adopted in this thesis.

The two data sets used for the purpose of studying the before and after situations differ in their sample size, objectives, and methods, and therefore the comparison is not straightforward, only a few indicators can be directly compared. Instead I will use each survey for different purposes and try to link the main findings as a way to understand the changes. The first data set, the1995 Household Survey conducted for the Transportation Master Plan for the City (JICA, 1996) will be used to understand the main forces underlying travel behavior in the city. This understanding is key to evaluate the possible changes in travel behavior as a new and better transportation system comes into place. However the analysis will result in new hypothesis rather than in proven facts. Some of those hypotheses will be tested, at least indirectly, through a look at the current situation. The "after" situation is described by a second data set, a revealed preference survey conducted by Transmilenio S.A. in May of 2002. The analysis of the after situation will look at the competition between the two public transportation modes; the incumbent traditional service delivery as described in the historical context, and the new mode described in the second to last section of the same chapter. In particular I will use the concept of value of time as a way to understand the changes and test the hypotheses proposed as a result of the first analysis.

In consequence, this chapter presents a summary of the two methodologies used in this thesis namely, Structural Equation Modeling and Discrete Choice Analysis; presents a literature review on the underlying forces of travel behavior and discusses general issues in regards to the subjective value of travel time.

Figure 3-1 Schematic description of the analytical approach



3.1 Structural Equation Modeling (SEM)

Travel behavior can be measured by a variety of indicators, which in turn may be caused by many variables. Thus, a study of the governing forces underlying travel behavior requires a method that can handle a variety of variables and relationships. Structural Equation Modeling (SEM) is a viable method because it is able to capture the multiple relationships and variables, some of them non-observable or latent in their nature. SEM is a confirmatory method guided by a priori hypothesis about the structures to be modeled (Kaplan, 2000, Mueller, 1996, Bollen, 1989). SEM as a methodological framework to study different transportation aspects has been used for about twenty-five years (Golob, 2001). The technique has been used in several areas like cross-sectional data analysis (Simma and Axhausen, 2001), longitudinal data analysis (Mokhtarian and Meenakshisundaram 1999) activity-based studies (Golob and McNally, 1994), and extended discrete choice models (Morikawa et. al (1996), Ben-Akiva et.al (1997), Morikawa and Sasaki (1998)).

In its more general case, it consists of a measurement model relating the observable to the latent variables and a structural model that relates the latent variables. Latent variables represent concepts of interest to researchers that are unobservable even in the population. Some of these concepts are typically ill defined, for example in the transportation field, concepts like mobility and accessibility could fit this description. The observable variables that serve as their indicators (i.e., trips, travel time, etc.) and their causes (income, population density, etc.) are typically measured in different ways, through a large number of variables across time and space, or are measured with error due to the sampling procedures or the data collection instruments. Nonetheless, the measurable (manifest) variables (x) can be used to make inferences about a set of latent variables ξ. The objective of latent variable models is to infer how the manifest variables (x) depend upon the latent variables (ξ). It assumes that there is a distribution of x conditional on ξ, $\Phi(x \mid \xi)$. If the density function of ξ is $h(\xi)$, then the marginal distribution of x is

$$f(x) = \int \phi(x|\xi) h(\xi) d\xi \qquad \textbf{(3-1)}$$

where the function f (x) is observable from the sample, however, in order to infer how x depend upon y there is need for assumptions about the form of f (x). The main assumption being "conditional independence" states that the manifest variables are independent of one another, given the values of the latent variables. This means that any observed interdependence between the manifest variables is due solely to their common dependence on the latent variables ruling out possible causality relationships among them. Factor Analysis is one known method of this kind; in fact, it is a specific case of structural equations modeling (Everitt, 1984, Bollen , 1989, Wansbeek and Meijer (2000), Kaplan (2000)).

A Structural Equations Model captures the relationships between exogenous and endogenous variables and between the endogenous variables themselves, it consists of a structural model and a measurement model. The structural model is defined by: (LISREL notation, Joreskog and Sorbom 1993 is adopted):

$$\eta = B\eta + \Gamma\xi + \zeta \tag{3-2}$$

in which the (m) endogenous latent variables denoted by η are a function of each other and of the (q) exogenous latent variables denoted by ξ. The unexplained portions of the endogenous variables, have a variance-covariance matrix defined by $\Psi = E\,[\zeta\zeta']$. In the general case, both η and ξ are considered latent endogenous and exogenous variables respectively. Observable variables with no measurement errors can also be included without loss of generality. The measurement model represent the relationships between the latent variables η and ξ, and its indicators x and y.

$$x = \Lambda_x\xi + \delta \tag{3-3}$$

$$y = \Lambda_y\eta + \varepsilon \tag{3-4}$$

where x is a set of (p) observed manifest variables considered as indicators of the explanatory variables (ξ), and δ is a vector representing the measurement errors in x. The matrix Λ_x (p x m) consists of regression weights of x on ξ. This is referred as the measurement equations. A similar approach can be conducted to define the structure for the endogenous latent variables following the equivalent measurement equation. The measurement errors (δ and ε) are uncorrelated with η, ξ, and ζ, but may be correlated among themselves. The modeler fixes some of the unknown parameters (i.e. elements of **B**, Γ, Ψ, $\Lambda_{x,}$ Λ_y) following a priori hypotheses. To set the scale (metric) of the latent variables equal to the one of the observed variables and give "meaning to the latent variable" some of the loading factors (λ) are set equal to one, that is one element in each column of Λ_y and Λ_x is set equal to 1. The free parameters are estimated simultaneously, together with their standard errors. Identification requires, among other conditions, that the matrix (I - B) must be non-singular. The estimation of a SEM-model is done in several ways (e.g. Maximum Likelihood, Generalized Least Squares, Weighted Least Squares) (Bollen, 1989 Joreskog and Sorbom, 1993). The methods are based on matching model-replicated variance-covariances with the observed variance-covariances from the sample; the application of a specific method depends mainly on the characteristics and assumptions regarding the data.

The estimates are the values for all parameters established by the model, these represent the effects that one variable has on others, typically the direct, indirect, and total effects are calculated. An effect can be understood as the magnitude of expected change in one variable for every change in the corresponding causing variable. The direct effects are those whose influences are unmediated by any other variable, they are given by the elements of the matrixes $\mathbf{B}$, $\mathbf{\Gamma}$, $\mathbf{\Lambda}_{x.}$ and $\mathbf{\Lambda}_{y.}$ The indirect effects are those mediated by other variables and can be obtained as the difference between the total and the direct effects. The total effects (direct and indirect) of the exogenous and endogenous variables on the endogenous variables are usually defined as the sum of powers of coefficient matrices or as reduced-form equations under certain convergence conditions (Bollen, 1987). In complex models the study of these effects is key because some of the indirect effects could cancel or reinforce the direct ones.

The model's goodness of fit is evaluated through a series of indices generated along with the estimation process, yet there is an on-going debate over the use of the different measures. The following indexes are typically reported (Bollen, 1989, Joreskog and Sorbom, 1993, Tanaka, 1993, Kline, 1998).

- The χ^2-value and its probability; under the assumption that the model is true and of multivariate normality, this statistic is interpreted as a test of significance of the difference between observed covariances and those implied by the model. However this index becomes less meaningful when large sample sizes are used (the χ^2-value is equal to (N-1) times the minimum value of the fit function) and when the multivariate normality assumption is violated. In the models being tested in this study the sample size is large, usually larger than 10,000 and therefore the use of this index is problematic.
- Goodness-of-Fit Index (GFI) and (AGFI): The GFI measures how much better the model fits as compared to no model at all, while the Adjusted Goodness-of-Fit (AGFI)

is a penalized GFI based on the number of parameters included in the model. Both of these indices should be between 0 and 1, with those values closer to 1 meaning better fit.

- Normed Fit Index (NFI): The NFI measures how much better the model fits as compared to a baseline model. Usually the baseline model is one where the observed variables are uncorrelated. Like the previous index, values closer to 1 indicate better fit.
- Critical Number (CN): The CN gives the sample size at which the χ^2-value would be just significant. In general CN > 200 suggest fair to good fit.
- Root Mean Square Error of Approximation (RMSEA): is based on the analysis of the residuals of the estimation accounting for model complexity, smaller values implying better fit.

3.2 Review of possible causes of travel behavior

A first step in the development of the a-priori hypotheses to be tested using a structural equations model for Bogotá is to look at previous studies that try to uncover causes of travel behavior. The literature on the subject is abundant and a comprehensive review is out of the scope of this work. In general, this study is based on the work of Lleras et.al (2002) where they define three main travel behavior indicators, namely:

a. Mobility Chances, measured as the access to private automobile
b. Mobility Level, measured as the number of daily trips per person
c. Mobility Intensity, measured as the total daily travel time

They showed that across several countries, these three indicators are influenced among themselves (endogenous relationships) and are associated with several exogenous variables (degree of urbanization, wealth, household structure and gender). Analyzing travel behavior at the country level they consistently found that whenever Mobility Chances increases, Mobility Level increases and Mobility Intensity decreases. That is, as a person's access to the private automobile increases, his or her daily trip rate increases but the total duration of his or her trips will decrease. However, as Mobility Level increases, Mobility intensity does it as well. The end result is that the increment in Mobility Level offsets the possible gains in Mobility Intensity. That is, a person's access to the private automobile increases the daily trip rate, which in turn causes that the possible gains in daily travel time resulting from shorter per trip duration, do not occur because of the increased number of daily trips. The total daily travel time may remain the same but the average trip duration may be reduced.

Concerning the exogenous effects, Wealth is positively associated with Mobility Chances but negatively to the Degree of Urbanization and the Household Structure. A similar work conducted by Timmermans et al. (2002), using an activity based approach, compared time allocation in urban settings between several countries, they found that the household context and the day of the week determine largely the number of activities and travel behavior, while the spatial context seems to play a less significant role. These findings are important to the present research insofar as they can serve to explore the inequalities between car users and public transportation users and how Wealth, Household Context, or the better provision of public transport can modify these conditions.

Other authors have looked at individual factors finding that auto ownership is a function of urban form (Newman and Kenworthy, 1989 and Kenworthy and Laube, 1999), other have criticized this view because it does not control for other relevant factors (Pickrell D., 1999) At a more aggregate level, Gakenheimer (1999), Schafer (2000), and Ingram and Liu (1999), have shown the effect of income growth in motorization. However very little work has been done to understand the governing forces in cities in developing countries where differences in urbanization, distribution of income, provision of public transport, participation in activities outside the household, and family structure may result in different causal relationships. The hypotheses used in this research stem in part from these studies and from the factors outlined in the first chapter of this thesis. They will be presented in the next chapter along with the estimation and discussion of the findings.

3.3 Discrete Choice Modeling

Disaggregate analysis of travel behavior has been widely used in many transportation applications because it allows the study of the choices made by travelers when confronted with different alternatives (Domenich and McFadden, 1975, Ben Akiva and Lerman, 1985). This analytical approach allows for testing the effects of different policies and permits the determination of utility functions and therefore the microeconomic study of travelers as consumers.

As pointed out in the summary of the previous chapter, the travel behavior indicator chosen as the underlying force driving the implementation of Transmilenio is travel time. In that sense, the first step of this analysis (i.e., Structural Equation Model) presents the factors that influence travel time. The second part of the analysis is meant to look at the decisions made by public transportation travelers when confronted with the new option. The response that customers exhibit will serve to analyze the impact of Transmilenio on travel time. The hypothesis is that improvements in public transportation will be reflected in the way travelers approach decisions regarding their choices, particularly the value that is given to travel time. This value (e.g., Marginal Rate of Substitution between time and money at constant utility) is understood as the willingness to pay for timesavings.

The main hypothesis is that when controlling for level of income (Pindyck and Rubinfield, 1998), opportunity cost of time (Small and Winston, 1999) and the inclusion of the two competing modes in the choice set (Ben Akiva and Lerman, 1985); if the value of time perceived when using Transmilenio is lower in a statistically way, than the one for the traditional system, then the utilization of the new mode implies benefits because a utilization of a minute in Transmilenio cost less that the utilization in the incumbent mode. This may result from an improvement in the traveling environment (comfort, safety, security, etc.) or because time savings have been already realized and due to diminishing marginal rates of substitution (Pindyck and Rubinfield, 1998) the willingness to pay for further savings is less.

Following, I present a summary of discrete choice analysis, in particular of a binary choice model, and how it may be used to test the foregoing hypothesis. Readers are referred to specialized books for a comprehensive review of the methodology, for instance Ben Akiva and Lerman (1985) from where I take most of the following description.

In Bogotá, as in many cities in developing countries, the majority of public transportation users are captive riders because access to the private automobile is very limited. In addition, non-captive riders hardly use public transport, that is, if a person is able to move using other modes different than public transport, it is very likely that he or she will not make use of it. Mohan in 1994, pointed out for Bogotá, that only above the eightieth income percentile people have the choice between the private automobile and other options, in the rest of the income spectrum the choices are basically non-motorized modes or public transport. Therefore, when a new public transportation mode is introduced under these circumstances a binary choice model to study the decisions of public transportation riders is appropriate. The assumption is that the choice set for the majority of the population is limited to the two public transportation alternatives. When faced with the choice set C_n, a person n will select the alternative i with a probability equal to

$$P_n(i) = \Pr(U_{in} \geq U_{jn}) \tag{3-5}$$

where U_{in} and U_{jn} are random variables representing the respective utility of alternatives i and j for person n. The utility function is divided into two parts, a systematic and a random component.

$$U_{in} = V_{in} + \varepsilon_{in} \tag{3-6}$$

Rewriting the expression for the probability of choosing alternative i the following expression is obtained:

$$\begin{aligned} P_n(i) &= \Pr(U_{in} \geq U_{jn}) \\ &= \Pr(V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn}) \\ &= \Pr(\varepsilon_{jn} - \varepsilon_{in} \leq V_{in} - V_{jn}) \end{aligned} \tag{3-7}$$

Therefore what matters is the difference between the components of the utility functions and not their absolute levels. The systematic component of the utility is generally assumed to be a function linear in the parameters; these parameters are functions of the attributes of the competing alternatives and characteristics of the decision maker. Therefore the systematic part can be written as:

$$V_{in} = \sum_k \beta_k x_{ink} \tag{3-8}$$

The random component, the disturbances, is assumed to have zero mean and a fixed scale. In general the derivation of the binary choice model follows an assumption about the distribution of the difference in disturbances thereby permitting the calculation of the probabilities. In general, it is assumed that the difference is normally distributed which gives rise to a probit model, or that is logistically distributed resulting in a logit model. The last one is typically the most widely use due to its closed form. It results in the following expression:

$$P_n(i) = \frac{e^{\mu V_i}}{e^{\mu V_i} + e^{\mu V_j}} \quad \textbf{(3-9)}$$

where μ is a positive scale parameter, typically 1. The estimation of the model, that is the estimation of the values of the coefficients (βs), is typically done using the Maximum Likelihood method. The estimation method yields the coefficients, their asymptotic standard errors and respective t-statistics. These statistics are useful to test the null hypothesis that a given coefficient is equal to zero. In addition to test the null hypothesis that all the parameters are zero a likelihood ratio test is performed. Other parameters typically reported are the measures ρ^2 and the adjusted ρ^2, they are analogous to the R^2 measure used in regression.

Whenever a discrete choice model is specified a comparison between modes is carried out. Since this method has been adopted by the professional practice, theoretically the comparison I mean to undertake is repetitive. In fact, during the planning stages of Transmilenio, one of such models was specified and used to forecast the demand (Steer Davies Gleave, 1999). It used stated preference data following the traditional approach when a new mode is being introduced and revealed preferences cannot be collected. The coefficients therefore may be biased as shown by Ben-Akiva and Morikawa (1990) thus; a study using revealed preference is worth developing. Even when the model is somehow consistent with actual ridership it is still relevant to confirm the actual behavior. Here in this study, a data set resulting from a revealed preference survey is used. Although this approach is usually regarded as "better", it is not free of problems namely; lack to represent the actual choice set, lack of variability in the attributes and possible multicolinearity resulting in not significant effects (Ben-Akiva and Morikawa, 1990, Ortuzar and Willumsen, 1994). These concerns will be kept in mind when analyzing the model.

When actual observations are possible then the suggested method is to combine RP and SP data to overcome the drawbacks and make use of the advantages of each data collection method (Ben- Akiva and Morikawa, 1990). In this study however, that approach was not undertaken and therefore should be a natural follow-up.

3.3.1 Discrete Choice Models as tools to analyze the competition between modes

As mentioned previously every time a discrete choice model is specified a comparison between modes is carried out. However specific work dealing with this comparison and analyzing the different attributes from the perspective of changes in travel behavior is not very common. In particular, very little work exists in regards to changes in the travel behavior in developing countries as better modes of public transportation are introduced to compete or replace the existing ones.

Usually the discussion has revolved around the competition between rail and bus alternatives, for instance the recent work of Ben-Akiva and Morikawa (2002). A parallel can be drawn between rail, being the equivalent of BRT, and bus being the equivalent of the traditional buses in mixed traffic. The assumption is that BRT is more attractive than the regular bus; all else being equal travelers will choose BRT. The indications that Ben-Akiva and Morikawa (2002) give about the reasons underlying this discussion apply to the case studied in this work. That is, BRTs are associated with higher reliability, comfort, and safety; while the traditional buses are seen as more flexible and direct. Interestingly, they found that for Washington DC, Metro service is preferred over bus services, however when buses operate in exclusive bus lane the preference towards Metro disappears.

Ben-Akiva and Morikawa (2002) also show that impact studies trying to capture the preference toward a given mode following a "before-and-after" approach, usually look at ridership changes, however those results are misleading because often the new mode replaces, to a large extent the old one, rather than compete. Another way to evaluate the preferences is through the alternative specific constant; its coefficient measures those attributes that are not being captured by the other attributes included in the utility function, that is the difference in the utility function all else being equal (Ben-Akiva and Lerman, 1985). However, Ben-Akiva and Morikawa point out the following issues with this approach; first when the two modes do not run in parallel corridors then the comparison is troublesome, and second the constant may also capture constraints defined for instance by socioeconomic characteristics rather than by mode attributes. In addition, this approach will only hold if all the coefficients for the remaining attributes are generic.

The integration of choice models and latent variable models has also been suggested to capture those attributes that are hard to measure but represent the preference towards a given mode. Furthermore, these methods rather than just stating which mode is preferred (i.e., through the alternative specific method) allow the researcher to measure the effect of this "latent" attributes (reliability, information availability, comfort, safety, security, accessibility, etc) on ridership (Morikawa et. al (1996), Ben-Akiva et. al (1997), Morikawa and Sasaki (1998)). However, this approach was not adopted in this study.

Since the objective of this study is to measure the impacts emerging from changes in travel behavior, one option would be to analyze how the two modes are competing following one of the mentioned approaches; however I suggest the study of the willingness to pay for travel time as an indicator of improvements, and indirectly of preference, in travel time as presented in the following section.

3.3.2 Value of Time

Value of time is understood in this work as the marginal rate of substitution (trade-off) between travel time and monetary cost at constant utility (Domencich and McFadden 1975, Ben Akiva and Lerman, 1985, Ortuzar and Willumsen, 1994). Given a utility function V for the alternative i and individual n:

$$V_{in} = \sum_{k} \beta_k x_{ink} \tag{3-10}$$

the marginal rate of substitution (value of time) between two attributes, say X_1 (measured in minutes) and X_2 (measured in monetary units) can be obtained as:

$$VOT = -\left.\frac{dX_2}{dX_1}\right|_{V_i} = \frac{\dfrac{\partial V_i}{\partial X_{1i}}}{\dfrac{\partial V_i}{\partial X_{2i}}} \tag{3-11}$$

which for cases where all attributes are linear in the parameters and individually introduced in the utility function, for instance in $V = \beta_1 X_1 + \beta_2 X_2$, is equal to the ratio of the coefficients of time and cost.

$$VOT = \frac{\beta_1}{\beta_2} \tag{3-12}$$

Similarly one can evaluate the marginal rate of substitution between any pair of attributes given a utility level. It is important to stress that the marginal rates of substitution are random variables and therefore their significance may be evaluated according to the expression described by Jara Diaz et.al. (1988).

$$t=\left(\sqrt{\frac{\sigma_t^2}{\beta_t^2}+\frac{\sigma_c^2}{\beta_c^2}-\frac{2Cov(\beta_t,\beta_c)}{\beta_t\beta_c}}\right)^{-1} \tag{3-13}$$

Hence, value of time can be seen as an indirect measure of how "distasteful" or "painful" is to travel inasmuch as it measures the willingness to pay to save time. Previous studies have found some general trends in regards to comparative values that support the view that improvements in travel time can be studied through comparing different values of time. Times that are perceived as having a lower quality or contribute less to the "happiness" of a person correspond to higher values. Confirming the conventional results, previous studies done for the case of Bogotá have found that the higher the persons' wealth, the higher the willingness to pay for time savings (Steer Davies Gleave, 1999), and in-vehicle travel time is less burdensome than waiting or walking time (Kozel, 1986, Steer Davies Gleave, 1999).

3.4 Conclusion

The analytical approach to understand the changes resulting from travel behavior was presented in this chapter. First, the relationships governing travel behavior will be studied through a Structural Equation Model. The analysis will pay special attention to the factors that influence travel time mainly for those that do not have access to the private automobile. Uncovering these forces is key to understand how Transmilenio may reduce inequalities in travel time and what other possibilities beyond the new transportation mode can be explored to reach the same goal. Although this is a picture of the situation before the introduction of the new system, many areas of the city are still subject to the same forces since they are not being covered by the new alternative. The results of this analysis would provide the elements to justify an investment like Transmilenio as a way to improve the equity in terms of access to transportation.

Next, the study will shift to the analysis of how public transportation users facing the decision between Transmilenio and the traditional system approach their choice making process. That analysis will be carried out through a discrete choice model allowing an understanding of the marginal rates of substitution between the different attributes of each mode. In particular, the value of time will constitute the main parameter used as a proxy for the measurement of benefits in travel timesavings and quality of the displacements.

The review of the methodologies used to compared different modes suggest that further research adopting the discrete choice approach should involve a combined data set (RP + SP) and integrate latent variables to capture "hard to measure" attributes. This model will allow the identification and understanding of preferences in addition to the evaluation of improvements in travel time. It will also prove beneficial in terms of studying policy alternatives. Nevertheless, due to lack of these data this strategy was not adopted for this study.

4 The travel behavior in Bogotá

Aggregate data for Bogotá from the 1995 Household Survey have been widely used by the government, NGOs, consultants, the community, and the transportation industry to argue against or for policies or infrastructure development. In particular, the data have been used to support the creation of Transmilenio as shown in the following statements from an official document: [13]

> *The mean speed of the public transportation buses is 10 Km/hr. In addition, and despite a market share of 72% of the daily trips; the buses, minibuses, and vans shared the road space with private vehicles, taxis and trucks typically circulating on the slow lane of the main roads in our city.*
>
> *On an average day, a bus rider spends 2 hours and 20 minutes traveling, which compared to the time spent by citizens of other cities in Latin America and the rest of the world is excessive.*
>
> *The numbers, according to the JICA study, are evident, those bogotanos reaching 70 years old spent on average 10 years of their life in a bus.*

Those claims sought to build a consensus around the fact that public transportation users (the majority of the population) were subject to poor levels of service while users of automobiles (a disproportionate minority) enjoyed better conditions, moreover, spent much less time in transportation. Thus, equity measured as differences in travel time, was the focus of the discussion; the inequalities emerged from income differences (i.e., car ownership), the inadequate use of the road space, and the poor service provided by the public transportation service. Other factors like home or job location in the city, household structure, occupation, etc. were not accounted for as possible causes. Hence, Transmilenio appeared as a solution inasmuch as it could reduce travel time for public transportation users and contribute in shrinking the travel time gap between buses and cars. The underlying message was that the solution for the mobility (not accessibility) barriers hinged upon an improved public

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[13] Transmilenio, Un Sistema de Vida. Transmilenio S.A. Bogota, December 2000.

transportation system. Thus, the objective of this chapter is to uncover those hypothesized relationships governing travel behavior in Bogotá existing in 1995 and understand the changes that Transmilenio could have brought about and the situation for those who still do not have access to the new mode.

As outlined in the foregoing chapter, the study of relationships governing travel behavior through Structural Equation Modeling entails testing whether a series of hypotheses (causal relationships) match the existing data. Hence this chapter is organized as follows, first I present a general overview using aggregate data to describe travel patterns and restate the abovementioned hypotheses; subsequently I present the results of the SEM exercise that tests those hypotheses, and conclude with an analysis of the results extrapolating how modifications brought about by Transmilenio could operate into the causal structure described by the model.

4.1 General overview and a priori hypotheses

The analysis of the 1995 Household Survey's raw data confirms the general picture presented by the quotes from the Transmilenio document albeit differences with the numbers traditionally used. [14] Table 4-1, Table 4-2, present the main data supporting the arguments.

Table 4-1 Modal share of daily total trips in Bogotá in 1995

Mode	Trips	Share of Total	Share of Motorized
Non-Motorized (Walking and Bicycle)	3,289,749	22.8%	-
Motorized Two-Wheelers	53,919	0.4%	-
Automobile	2,143,184	14.8%	19%
Taxi	575,669	4.0%	5%
Public Transport	7,201,992	49.9%	65%
Others	1,170,362	8.1%	11%
Total	14,434,876	100.0%	100%

Others include school buses, private company buses, trucks, etc.

[14] The differences may arise from the author's treatment of outliers, missing data, and the classification of modes pertaining the analysis presented in this research.

Table 4-2 Mean trip travel time in Bogotá in 1995 by mode

Mode	Mean (Min)	Variance (Min)	Coefficient of Variation	Lower Bound (99% CI)	Upper Bound (99% CI)
Non-Motorized (Walking and Bicycle)	14.50	4.95	1.188	14.33	14.66
Motorized Two-Wheelers	32.06	13.66	0.893	29.83	34.28
Automobile	42.65	20.44	0.821	42.10	43.21
Taxi	40.42	17.75	0.807	39.40	41.45
Public Transport	66.82	32.99	0.666	66.45	67.19
Others	52.26	19.83	0.660	51.17	53.35

Others include school buses, private company buses, trucks, etc.

Table 4-3 Trip rates by mode in Bogotá in 1995.

Mode	Mean (Trips per Day)	Variance (Trips per Day)	Coefficient of Variation	Lower Bound (99% CI)	Upper Bound (99% CI)
Non-Motorized (Walking and Bicycle)	2.05	0.63	0.39	2.04	2.07
Motorized Two-Wheelers	2.17	1.52	0.57	1.98	2.35
Automobiles	2.41	2.09	0.60	2.36	2.46
Taxi	1.77	1.20	0.62	1.71	1.83
Public Transport	1.71	0.40	0.37	1.70	1.72
Others	1.84	0.30	0.30	1.82	1.87

Others include school buses, private company buses, trucks, etc.

Table 4-3 presents a dimension of inequality unexplored by the previous use of the aggregate data. Over a sample size of 64,182 person-trip records, on average, people traveling mainly by automobile, have a daily trip rate of 2.41, whereas public transportation users complete on average 1.70 trips per day. That is, with a probability of 99%, auto users make 0.7 more trips than public transportation riders. This finding implies that the chances of accessing job opportunities, education, or amenities in general, are lower for public transportation riders than for auto riders assuming that the willingness to participate in all those activities is similar across the whole population.

In general, the three indicators of travel behavior presented in the foregoing tables confirm that:

- The majority of trips correspond to public transportation trips
- Public Transportation trips, on average, take longer than trips on automobile
- Car riders complete on average more trips than bus riders

Hence, the following hypotheses:

1. Access to private automobile increases the trip rate and decreases total daily travel time.
2. Regardless of the transportation mode, higher trip rates result in greater total daily travel time.
3. A person living in a wealthy household will have better chances of traveling in an automobile.
4. A person living in a larger household is more tightly constrained regarding traveling opportunities, than one in a smaller household.
5. A person living in an area where employment is abundant will spend less travel time than one person living in an area where employment is scarce.
6. A person living in an area where population density is high will tend to rely more in non-motorized and public transportation modes than one person living in low-density areas. Underlying this hypothesis is the assumption that higher population densities entail higher density of other activities and services.

A key assumption of the model is that the supply of public transportation is evenly distributed in the city. As shown in Figure 4-1 the public transportation network is ample and covers most of the urban area, in reality one can say that every person in Bogotá in 1995 had access to a public transportation route within 500 meters from the household location. Modeling the situation of 1978, Kozel (1986), also in Mohan, (1994) showed that only proximity to "buseta" routes[15] was significant for those having access to both public

[15] See Chapter 2, for the description of the"buseta" mode in the mode 1970s

transport and the private automobile. For everyone else, proximity to bus routes was not a significant determinant of traveling behavior.

Figure 4-1 Public Transportation Network as 1995

The darker color represents the urban area where the household survey was conducted.

Source: Map prepared from data provided by Transmilenio S.A.

4.2 Model Specification

The hypotheses can be expressed in terms of its corresponding Structural Equation Model (Equations 4.1, 4.2 and 4.3) or as a path diagram (Figure 4-2):

Equation 4-1 Structural Model

$$\begin{bmatrix} Mobility\_Chances \\ Mobility\_Level \\ Mobility\_Intensity \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ \beta_{21} & 0 & 0 \\ \beta_{21} & \beta_{22} & 0 \end{bmatrix} \begin{bmatrix} Mobility\_Chances \\ Mobility\_Level \\ Mobility\_Intensity \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & \gamma_{14} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \gamma_{24} \\ \gamma_{31} & \gamma_{32} & \gamma_{33} & \gamma_{34} \end{bmatrix} \begin{bmatrix} Employment\_Orientation \\ Wealth \\ Household\_Structure \\ Degree\_of\_Urbanization \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \end{bmatrix}$$

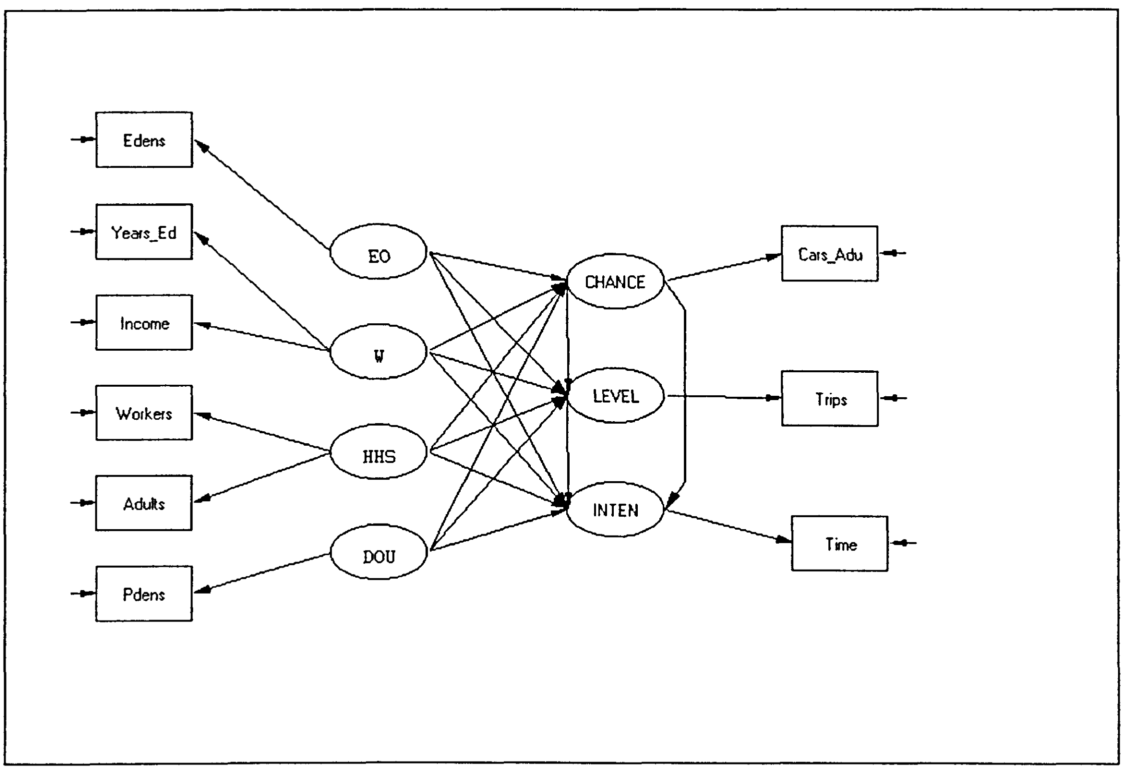
Equation 4-2Measurement model (I)

$$\begin{bmatrix} cars/adults \\ trips \\ travel\_time \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} Mobility\_Chances \\ Mobility\_Level \\ Mobility\_Intensity \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

Equation 4-3 Measurement model (II)

$$\begin{bmatrix} Employment\_Density \\ Income \\ Years\_Ed \\ Adults \\ Workers \\ Population\_Density \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & \lambda_{31} & 0 & 0 \\ 0 & 0 & \lambda_{41} & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} Employment\_Orientation \\ Wealth \\ Hosuehold\_Structure \\ Degree\_of\_Urbanization \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix}$$

Figure 4-2 Path Diagram of Structural Equation Model for Bogotá



Where the exogenous variable EO stands for employment opportunities and is meant to capture the job potential in the vicinity of the household location, W stands for wealth and is meant to capture the stock of material resources that a person has available, HHS stands for household structure and is meant to capture the constraints imposed on a person as a result of the number of people sharing the wealth or the available vehicles. Finally DOU stands for population orientation and describes basically population density in the area where the household resides. The endogenous variables, CHANCE corresponds to private mobility chances, which measures the access to private vehicles, LEVEL corresponds to the daily number of trips, and INSTENS to the daily travel time. Note that EO and DOU do not have a measurement error and therefore their respective indicators are assumed to be their true values. Although problematic from a conceptual point of view, this assumption represents a compromise between model specification and model estimation. In general, in order to test the same model over several samples, the model has to be less complex.

It is assumed that the relationships underlying the production of public transportation trips are different from those producing trips in the private automobile. It is also assumed that distance from the CBD (i.e., distance from jobs, and other amenities), which in the case of Bogotá is inversely correlated to income, (i.e., the higher income levels are typically closer to the CBD) also plays a role in travel behavior, hence six different models will be estimated for the corresponding market segments presented in Table 4-4.

Table 4-4 Market segments

	Trips by mode	
Distance from CBD	(1) Center and Public Transportation Trips	(4) Center and Private Transportation Trips
	(2) Ring 1 and Public Transportation Trips	(5) Ring 1 and Private Transportation Trips
	(3) Ring 2 and Public Transportation Trips	(6) Ring 2 and Private Transportation Trips

Table 4-5 presents the main characteristics of the three geographically determined market segments. In general as distance from CBD increases, the income level decreases along with vehicle ownership and trip rates. Proportion of public transportation trips increases as well as travel time. Household size and number of children also grows but not the number of workers per household. The Center and the first Ring are similar in many of the socioeconomic characteristics but differ in the ratio of population to job density, which serves as a proxy for one of the hypothesized relationships. Figure 4-3 presents the geographical distribution of the three segments.

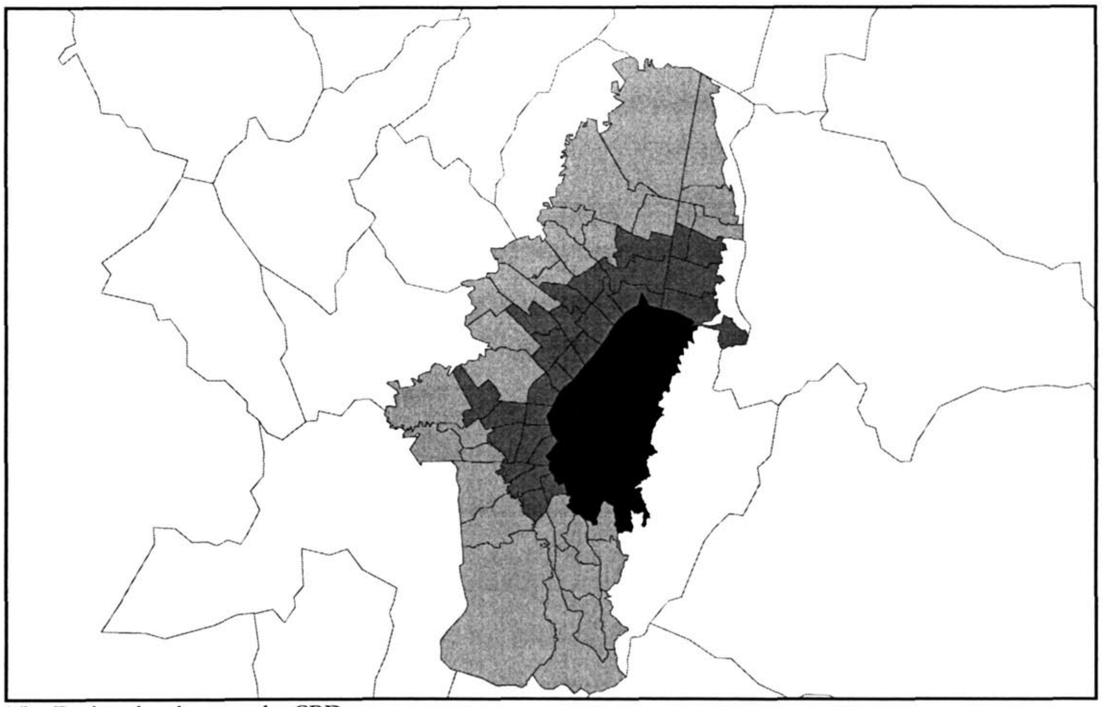
Table 4-5 Description of market segmentation by distance to CBD (Mean values)

	Center	Ring1	Ring2
Years of Education (Adults)	10.44	10.33	7.70
Total Number of Trips per person	1.96	1.88	1.60
Total Daily Travel Time (min), mean calculation includes non travelers	73.24	85.46	92.28
Number of Daily Journeys	0.85	0.84	0.77
Non-Motorized Trips per person per day and Share	0.54 (28%)	0.44 (24%)	0.43 (26%)
Public Transportation Trips per person per day and Share	1.01 (53%)	1.04 (56%)	1.10 (65%)
Private Transportation Trips per person per day and Share	0.33 (17%)	0.35 (19%)	0.12 (8%)
Household Size	5.2	5.2	5.4
Number of Children	1.3	1.3	1.9
Household Monthly Income (1995 Col $) and (1995 US$)	Col $ 699,755 US$ 799.2	Col $ 688,424 US$ 786.87	Col $ 374,948 US$ 428.51
Number of vehicles per Household	0.52	0.54	0.18
Number of Workers per Household	2.3	2.3	2.1
Population Density (people/ sq. kilometer)	18,805	22,154	20,210
Employment Density (jobs/ sq. kilometer)	15,161	6,752	2,613
Housing Density (housing units/ sq. kilometer)	3,531	3,866	3.357
Distance from CBD (Km)	4.6	10.1	12.9

Source: Estimations over 1995 JICA Household Survey.

A journey is defined as a round trip with origin in the place of residence; a Journey is comprised of at least two trips.

Figure 4-3 Geographic location of market segments



The Darker the closer to the CBD

4.3 Model Estimation and Results

The models were estimated using the Maximum Likelihood method in the LISREL software.[16] The variables were scaled as follows:

- Employment Orientation: [jobs / square kilometers]/ 10,000
- Degree of Urbanization: [persons / square kilometers] / 10,000[17]
- Wealth: [1995 col$] / 1,000,000
- Household Structure: [Number of Workers per household]
- Private Mobility Chances: [cars per household/adults per household] * 10
- Mobility Level: [trips]
- Mobility Intensity: [minutes] / 100

[16] LISREL 8.51 Scientific Software International, Inc, Copyright ©2001

[17] Jobs, persons and area are based on the TAZ established in the Transportation Master Plan 1995. JICA (1995)

In general the model representation of the data is good (Table 4-6). The signs match the hypothesized relationships and most of the direct associations are significant at the 95% confidence level.

Table 4-6 Goodness of Fit measures

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Sample Size	10,568	13,690	22,172	10,568	13,690	22,172
χ^2 (DF)	353.51 (11)	668.88 (11)	1008.65 (11)	368,32 (11)	718.3 (11)	926.34 (11)
GFI / AGFI/	0.99 / 0.97	0.99 / 0.96 /	0.99 / 0.95 /	0.99 / 0.96 /	0.99 /0.85	0.99 / 0.96 /
NFI	/ 0.98	0.97	0.98	0.97	/0.97	0.97
RMSEA	0.05378	0.06561	0.06378	0.05988	0.06795	0.06111
CN	740.08	507.02	544.49	710.37	472.21	592.78

Table 4-7 presents the squared multiple correlation for the individual equations representing the endogenous variables for each of the six models. In general the explained variation is fair for Private Mobility Chances across all segments. However, the variation of Mobility Intensity is better explained in the case of public transportation and the one of Mobility Level in the case of private transportation. In the remaining cases the correlation is rather poor suggesting that perhaps the model is still worth of refinement and the inclusion of additional variables may be explored.

Table 4-7 Squared Multiple Correlations for Endogenous Variables

Model	R^2 Mobility Chances	R^2 Mobility Level	R^2 Mobility intensity
Model 1 (Transit Trips)	0.453	0.073	0.414
Model 2 (Transit Trips)	0.531	0.068	0.438
Model 3 (Transit Trips)	0.355	0.081	0.545
Model 4 (Auto Trips)	0.458	0.229	0.097
Model 5(Auto Trips)	0.539	0.309	0.115
Model 6(Auto Trips)	0.356	0.256	0.083

The coefficients and effects are presented in Table 4-8, Table 4-9, Table 4-10, and Table 4-11.

Table 4-8 Coefficients for Public Transportation Trips

Public Transportation Trips	Γ (Direct Effects of ξ on η)				B (Direct Effects of η on η)		
	Employment Orientation	Degree of Urbanization	Wealth	Household Structure	Mobility Chances	Mobility Level	Mobility Intensity
Center							
Mobility Chances	0.0018 (0.0150) 0.1194	0.0847 (0.0439) 1.9297	3.1957 (0.1449) 22.0604	-0.6453 (0.0347) -18.5911	-	-	-
Mobility Level	-0.0233 (0.0077) -3.0308	0.1745 (0.0200) 8.7426	0.7163 (0.0824) 8.6936	-0.1117 (0.0200) -5.5888	-0.1834 (0.0120) -15.2212	-	-
Mobility Intensity	0.0049 (0.0037) 1.3208	0.0696 (0.0096) 7.2589	0.2689 (0.0387) 6.9573	-0.0523 (0.0095) -5.5210	0.0091 (0.0059) 1.5493	0.3782 (0.0052) 72.2015	-
Ring 1							
Mobility Chances	-0.5514 (0.1120) -4.9223	0.1011 (0.0586) 1.7247	3.0267 (0.1347) 22.4762	-0.6214 (0.0286) -21.7255	-	-	-
Mobility Level	-0.2377 (0.0492) -4.8275	0.1544 (0.0215) 7.1904	0.5263 (0.0693) 7.5897	-0.0785 (0.0157) -5.0017	-0.1781 (0.0109) -16.3189	-	-
Mobility Intensity	-0.2575 (0.0289) -8.9138	0.1105 (0.0132) 8.3975	0.4333 (0.0444) 9.7514	-0.0462 (0.0094) -4.9266	-0.0046 (0.0070) -0.6524	0.4254 (0.0053) 79.6610	-
Ring 2							
Mobility Chances	-0.1520 (0.0987) -1.5405	-0.0437 (0.0142) -3.0912	3.9211 (0.1251) 31.3431	-0.2922 (0.0137) -21.3050	-	-	-
Mobility Level	-0.3420 (0.0664) -5.1474	0.0621 (0.0094) 6.5745	1.6226 (0.0981) 16.5392	-0.0408 (0.0097) -4.1943	-0.2088 (0.0097) -21.5942	-	-
Mobility Intensity	-0.1976 (0.0347) -5.6998	0.0020 (0.0050) 0.4046	0.4533 (0.0490) 9.2437	-0.0144 (0.0050) -2.8758	0.0194 (0.0051) 3.8070	0.5694 (0.0043) 133.2522	-

Underlined coefficients are not significant at the 95% confidence level.

Table 4-9 Coefficients for Private Transportation Trips

Private Transportation Trips	Γ (Direct Effects of ξ on η)				B (Direct Effects of η on η)		
	Employment Orientation	Degree of Urbanization	Wealth	Household Structure	Mobility Chances	Mobility Level	Mobility Intensity
Center							
Mobility Chances	0.0012 (0.0151) 0.0824	0.0954 (0.0443) 2.1523	3.2718 (0.1476) 22.1725	-0.6511 (0.0350) -18.6081	-	-	-
Mobility Level	0.0001 (0.0059) 0.0189	0.0372 (0.0157) 2.3605	0.6465 (0.0681) 9.4884	-0.1136 (0.0159) -7.1568	0.1079 (0.0097) 11.0975	-	-
Mobility Intensity	-0.0040 (0.0047) -0.8435	0.1341 (0.0125) 10.7549	0.4764 (0.0554) 8.5929	-0.0825 (0.0128) -6.4533	-0.0798 (0.0073) -10.9367	0.1486 (0.0092) 16.1086	-
Ring 1							
Mobility Chances	-0.6056 (0.1148) -5.2756	0.1309 (0.0602) 2.1766	3.1425 (0.1400) 22.4473	-0.6285 (0.0291) -21.5654	-	-	-
Mobility Level	-0.2726 (0.0472) -5.7733	0.1424 (0.0223) 6.3944	0.9114 (0.0796) 11.4494	-0.1181 (0.0156) -7.5789	0.0680 (0.0118) 5.7744	-	-
Mobility Intensity	-0.3473 (0.0388) -8.9437	0.1709 (0.0181) 9.4613	0.5990 (0.0664) 9.0160	-0.0717 (0.0129) -5.5734	-0.0977 (0.0085) -11.4507	0.1374 (0.0114) 12.0526	-
Ring 2							
Mobility Chances	-0.1447 (0.0985) -1.4690	-0.0430 (0.0142) -3.0360	3.8776 (0.1232) 31.4782	-0.2983 (0.0138) -21.6667	-	-	-
Mobility Level	-0.1666 (0.0336) -4.9637	0.0046 (0.0048) 0.9615	0.8340 (0.0494) 16.8733	-0.0398 (0.0050) -7.9025	0.1070 (0.0049) 21.7117	-	-
Mobility Intensity	-0.3626 (0.0532) -6.8189	0.0364 (0.0075) 4.8328	1.2419 (0.0819) 15.1725	-0.0355 (0.0080) -4.4424	-0.1120 (0.0073) -15.3598	0.1245 (0.0133) 9.3876	-

Underlined coefficients are not significant at the 95% confidence level.

Table 4-10 Total Effects for Public Transportation Trips

Public Transportation Trips	**Total Effects of ξ on η**				**Total Effects of η on η**		
	Employment Orientation	**Degree of Urbanization**	**Wealth**	**Household Structure**	**Mobility Chances**	**Mobility Level**	**Mobility Intensity**
Center							
Mobility Chances	0.0018 (0.0150) 0.1194	0.0847 (0.0439) 1.9297	3.1957 (0.1449) 22.0604	-0.6453 (0.0347) -18.5911	-	-	-
Mobility Level	-0.0236 (0.0075) -3.1368	0.1590 (0.0184) 8.6378	0.1302 (0.0442) 2.9493	0.0067 (0.0153) 0.4359	-0.1834 (0.0120) -15.2212	-	-
Mobility Intensity	-0.0041 (0.0047) -0.8675	0.1305 (0.0118) 11.1031	0.3473 (0.0301) 11.5405	-0.0557 (0.0097) -5.7588	-0.0603 (0.0079) -7.5992	0.3782 (0.0052) 72.2015	-
Ring 1							
Mobility Chances	-0.5514 (0.1120) -4.9223	0.1011 (0.0586) 1.7247	3.0267 (0.1347) 22.4762	-0.6214 (0.0286) -21.7255	-	-	-
Mobility Level	-0.1395 (0.0453) -3.0821	0.1364 (0.0193) 7.0634	-0.0126 (0.0376) -0.3364	0.0321 (0.0120) 2.6758	-0.1781 (0.0109) -16.3189	-	-
Mobility Intensity	-0.3143 (0.0329) -9.5482	0.1681 (0.0148) 11.3622	0.4140 (0.0304) 13.6308	-0.0297 (0.0086) -3.4391	-0.0803 (0.0092) -8.6930	0.4254 (0.0053) 79.6610	-
Ring 2							
Mobility Chances	-0.1520 (0.0987) -1.5405	-0.0437 (0.0142) -3.0912	3.9211 (0.1251) 31.3431	-0.2922 (0.0137) -21.3050	-	-	-
Mobility Level	-0.3102 (0.0624) -4.9723	0.0712 (0.0091) 7.8644	0.8037 (0.0598) 13.4470	0.0202 (0.0081) 2.4824	-0.2088 (0.0097) -21.5942	-	-
Mobility Intensity	-0.3772 (0.0510) -7.3963	0.0417 (0.0074) 5.6449	0.9871 (0.0515) 19.1699	-0.0086 (0.0066) -1.2974	-0.0995 (0.0079) -12.6039	0.5694 (0.0043) 133.2522	-

Underlined coefficients are not significant at the 95% confidence level.

Table 4-11 Total Effects for Private Transportation Trips

Private Transportation Trips	Total Effects of ξ on η				Total Effects of η on η		
	Employment Orientation	Degree of Urbanization	Wealth	Household Structure	Mobility Chances	Mobility Level	Mobility Intensity
Center							
Mobility Chances	$\underline{0.0012}$ $\underline{(0.0151)}$ $\underline{0.0824}$	0.0954 (0.0443) 2.1523	3.2718 (0.1476) 22.1725	-0.6511 (0.0350) -18.6081	-	-	-
Mobility Level	$\underline{0.0002}$ $\underline{(0.0066)}$ $\underline{0.0375}$	0.0475 (0.0178) 2.6727	0.9995 (0.0531) 18.8374	-0.1838 (0.0143) -12.8657	0.1079 (0.0097) 11.0975	-	-
Mobility Intensity	$\underline{-0.0040}$ $\underline{(0.0047)}$ $\underline{-0.8573}$	0.1336 (0.0118) 11.2784	0.3640 (0.0309) 11.7599	-0.0579 (0.0097) -5.9542	-0.0637 (0.0082) -7.8056	0.1486 (0.0092) 16.1086	-
Ring 1							
Mobility Chances	-0.5514 (0.1120) -4.9223	0.1309 (0.0602) 2.1766	3.1425 (0.1400) 22.4473	-0.6285 (0.0291) -21.5654	-	-	-
Mobility Level	-0.3137 (0.0482) -6.5153	0.1513 (0.0241) 6.2828	1.1250 (0.0545) 20.6442	-0.1608 (0.0123) -13.1071	0.0680 (0.0118) 5.7744	-	-
Mobility Intensity	-0.3312 (0.0334) -9.9054	0.1789 (0.0152) 11.7712	0.4467 (0.0320) 13.9804	-0.0324 (0.0087) -3.7230	-0.0883 (0.0099) -8.9324	0.1374 (0.0114) 12.0526	-
Ring 2							
Mobility Chances	$\underline{-0.1447}$ $\underline{(0.0985)}$ $\underline{-1.4690}$	-0.0430 (0.0142) -3.0360	3.8776 (0.1232) 31.4782	-0.2922 (0.0137) -21.3050	-	-	-
Mobility Level	-0.1821 (0.0382) -4.7652	$\underline{0.0000}$ $\underline{(0.0055)}$ $\underline{-0.0007}$	1.2488 (0.0441) 28.3331	-0.0717 (0.0051) -13.9541	0.1070 (0.0049) 21.7117	-	-
Mobility Intensity	-0.3690 (0.0509) -7.2480	0.0412 (0.0074) 5.5707	0.9632 (0.0506) 19.0312	$\underline{-0.0110}$ $\underline{(0.0067)}$ $\underline{-1.6453}$	-0.0986 (0.0079) -12.4971	0.1245 (0.0133) 9.3876	-

Underlined coefficients are not significant at the 95% confidence level.

4.4 Analysis of Results

The structural equations models confirm the hypothesized relations. The analysis of the results will look separately at the endogenous (those between the travel behavior indicators) and exogenous (those of the exogenous variables on the travel behavior indicators) effects. Following, is the analysis of the main results based on the total effects described in Table 4-10 and Table 4-11. For reference, I will redefine the main mobility indicators. Private Mobility Chances measures the access to private vehicles, Mobility Level corresponds to the daily number of trips, and Mobility Intensity to the daily travel time.

4.4.1 Endogenous Effects

One understandable result confirmed by the model is the positive influence of the level of travel on the intensity of travel; that is, the higher the number of trips the greater the duration of travel during the day. This effect is consistent and significant across all market segments. However there are differences in the magnitudes; first, the effect that the level of public transportation trips has on mobility intensity is stronger (more than double) than the level of private transportation trips. This relation implies that, all else being equal, total time spent in transportation increases whenever the share of public transportation trips grows. In addition, when geography is incorporated in the analysis the difference in the effects is larger; if one lives further away from the city center and utilizes public transport, one will spend much more time traveling than everyone else.

The second effect is that of Mobility Chances on Mobility Intensity, which consistently shows, in accordance with the first finding, that higher access to automobiles lowers the total daily travel time. Again, the effect grows as one distances from the city center. Finally, to reinforce the first finding, the third effect shows that as Mobility Chances increases, the number of trips done in public transportation decreases and the number of trips in private transportation increases.

Concluding, the endogenous effects show that access to the private vehicle causes lower utilization of public transportation and thereby a decrease in the total daily travel time. In addition, as one distances from the city center the effects are aggravated. These effects agree with conventional ways to look at transportation in urban settings but do not provide new insights.

4.4.2 Exogenous Effects

The effects of the exogenous variables provide additional insights into the fundamentals of travel behavior in the city. The analysis will present first, the effects of location of housing and jobs in the city, and later the impact of wealth and the household context.

In general if one lives in an area where jobs are abundant, the results show that the three travel behavior indicators will tend to drop. That is, the number of cars per adult, the number of trips, and the daily total travel time will all decrease. The exception is the effect on Mobility Chances in the city Center where it functions in the opposite way. The effect on the number of vehicles per adult is greater in Ring 1 and not significant in Ring 2. The effect on Mobility Level operates differently over public and private trips when geography is considered. On the former it has a growing effect as one distance from the city center, by contrast the opposite occurs for the latter. Finally, the effect over Mobility Intensity is consistent over the two modes and increases as the distance from the city center grows. In conclusion, living in an area where jobs are abundant has greater benefits (in terms of travel time) for those living in the periphery regardless of the preference of transportation mode. The effect of the population density existing in the area where the person lives is positive on the three indicators except on Mobility Chances in the case of the outer ring. Interestingly, however, higher population densities result in higher Mobility Levels for the center in comparison to the first ring but on lower daily travel times.

In regards to the effect of wealth, all else equal, when it increases it affects all indicators positively regardless of location in the city or mode of preference. However, two specific effects are worth mentioning; first, in the outer ring the effect of wealth over Mobility Chances is stronger than in the other two areas; and second, the effect on private transportation trips is roughly consistent across the three sectors but, on public transportation trips is substantially stronger on the outer ring.

Finally, the effect of the household structure is consistent in the six markets in regards to Mobility Chances and Mobility Intensity. In those two cases, larger households cause fewer Mobility Chances and lower Mobility Intensity. By contrast, the effect on Mobility Level is positive for public transportation trips and negative for private transportation trips. In general, the closest to the city center the stronger the effects.

4.5 Conclusion

A study of the travel behavior as existed in Bogotá prior to the introduction of Transmilenio, and still governing travel behavior in areas where still is not an option, reinforces the view that public transportation riders are subject to greater daily travel time despite lower trip rates when compared to car users. Wealth is seen as a direct cause of higher car ownership and as the driving force of these disparities. Although the supply of public transportation did not play a direct role in the modeling exercise presented in this chapter, it is possible to argue that the low quality of the service is embedded in the inequalities. Nevertheless, wealth and the poor level of public transportation service must not be seen as the sole causes of the inequality. In addition the uneven distribution of jobs (mostly concentrated in the CBD) and the population (concentrated in the outer rings of the city), affects travel time and trip rates. Distance for jobs seems to be relevant as most of the effects were aggravated for people living in the outer ring.

Transmilenio, however, constitutes a response in an area where direct intervention could produce concrete results in the short-term as compared to land use changes or handling income distribution. In that sense, one can hypothesize some relationships in regards to the effects of Transmilenio in the fundamentals of travel behavior. However, to provide a definitive test a new household survey will be needed and the consequent model tested against the data. Lack of that data prevents a direct evaluation of the hypotheses in that way. However the following chapter approaches some of these issues and concludes that some of the changes are already taking place.

The hypotheses that can be extracted from the factors affecting travel behavior as contrasted with the objectives of Transmilenio are:

- For those using Transmilenio, the effect of Mobility Level on Mobility Intensity should be less than for those using the regular public transportation system. The effect must approximate that of the private vehicle.
- The effect of Mobility Chances on Mobility Level for public transportation trips should be reduced, and in the best case the sign reversed. That is, as the quality of the bus system approaches that of the private automobiles, the effect of having more vehicles per household would not result in a lower utilization of public transportation.

- Transmilenio alleviates some of the inequalities emerging from the geographical distribution of jobs and services but it does not solve the difference in the effects. That is people living closer to the CBD will still exhibit shorter travel times and possibly higher trip rates regardless of preferred mode.
- Transmilenio is not likely to produce substantial changes in the short term in the effects of job density or population density on mobility indicators. This is not to say that in the long term it could induce land use changes.
- In the long run, Transmilenio could change the effect of Wealth on Mobility Chances. That is, as public transportation improves it is less likely that given a certain wealth threshold value, people will buy automobiles; instead they will rely largely in transit.

5 The Competition between Transmilenio and the Traditional System.

It is worth starting this chapter by noting that in this thesis, the extent to which the hypothesized transformations outlined in the previous chapter occurs is primarily determined by the improvements in the level of service of public transportation rather than through the difficulties imposed to the use of the private automobile (e.g., car restrain policies or congestion). In fact, one can argue that in some corridors, the implementation of BRT may improve the conditions of the private vehicle despite the lost of one or two lanes. Once the buses that previously operated in mixed traffic are relocated to other corridors, and the BRT vehicles are channeled through the exclusive lanes, the capacity and speed on the general traffic lanes on the same corridors may increase. Hence, in this case one should look at the changes in behavior from the perspective of the public transportation rider rather than from that of the automobile user. However, if some automobile drivers shift to public transportation because the utility associated with choosing auto comes close to that of choosing transit, then the inequality gap will shrink even more.

The question that ultimately will shed some light about the changes in the level of service of public transport is: How riders perceive the attributes of the two modes (i.e., BRT vs. buses in mixed traffic), and in consequence how are they competing. As explained in the chapter describing the analytical framework, a discrete choice modeling approach is adopted to answer these questions. The data come from a revealed preference survey co-designed by the author and conducted by the Department of Transportation Planning of Transmilenio in May of 2002. The survey interviewed public transportation riders that declare having both, Transmilenio and the traditional system as viable alternatives to fulfill their traveling needs. The interviewees were met on the street while walking in areas where routes from the two systems run. They were asked to declare what mode they were going to use, describe the expected attributes of the trip in each mode, and some personal characteristics. A priori, two markets where identified, namely; those passengers starting their trip in the vicinity of the trunk corridors comprised the first segment, and those that do it in areas served by the integrated feeder lines comprised the second one. The surveys were conducted in areas outside the Central Business District capturing travelers in different neighborhoods of the city. The effect of the CBD is analyzed as a destination for the analyzed trip. The final sample size was 1151 for the first market segment and 945 for the second one.

In terms of the socioeconomic conditions the two markets are similar, although individuals in the second market tend to have a lower income level. By contrast, the segments differ in terms of their travel patterns as shown in Table 5-2 and Table 5-3. In general those in the first segment would correspond, roughly, to the first ring of the analysis of the previous chapter, and those in the second market to the outer or second ring.

Table 5-1 Main Characteristics of Travelers by Market Segments

Variable	Market Segment 1		Market Segment 2	
	Mean	Standard Deviation	Mean	Standard Deviation
In Calle 80	0.18	-	0.34	-
In Autopista Norte	0.16	-	0.10	-
In Caracas	0.66	-	0.01	-
In Tunal	-	-	0.35	-
In Usme	-	-	0.20	-
To Work	0.55	-	0.50	-
To CBD	0.62	-	0.56	-
Travel Alone	0.88	-	0.88	-
Prepaid Transmilenio	0.27	-	0.26	-
Need to be in destination on time	0.80	-	0.74	-
Weekly frequency of travel	4.54	1.48	4.30	1.65
Male	0.59	-	0.56	-
Female	0.41	-	0.44	-
Access to car in households	0.12	-	0.10	-
Live in own house	0.62	-	0.56	-
Receive wages and salaries	0.75	-	0.73	-
Married	0.52	-	0.48	-
Stratum 1 or 2 (Proxy for low income level)	0.48	-	0.63	-
Stratum 3 (Proxy for medium income level)	0.44	-	0.35	-
Stratum 4 or 5 or 6 (Proxy for high income)	0.08	-	0.02	-
Years of Education	12.14	3.05	11.98	3.17

Table 5-2 Attributes of Transmilenio by Market Segment

Variable	Market Segment 1		Market Segment 2	
	Mean	Standard Deviation	Mean	Standard Deviation
Market Share	0.66	-	0.70	-
Walking to Transmilenio Station or Feeder Bus Stop (min)	6.12	3.56	4.75	2.66
Waiting Time (Feeder) (min)	-	-	6.51	3.25
In-Vehicle-Travel Time (Feeder) min	-	-	10.21	4.22
Purchasing ticket and entering station (min)	3.50	2.19	2.95	2.47
Waiting Time (min)	4.92	2.16	4.96	2.72
In-Vehicle-Travel Time (min)	28.72	14.02	31.19	14.02
Exiting Station (min)	3.34	2.10	3.18	2.29
Walking to final destination (min)	6.80	4.55	6.73	4.13
Total Travel Time (min)	53.41	16.43	70.46	17.93
% In-Vehicle-Time	53.7 %	-	58.7 %	-
% Out-Vehicle-Time	46.3 %	-	41.3 %	-
Number of Transfers	0.11	0.35	1.11	0.34
Total Trip Cost (Col $ 2002) and (US$ 2002)	944.57 - 0.411	189.3	937.79 - 0.408	195.77
Chances of being seated	0.15	-	0.42	-

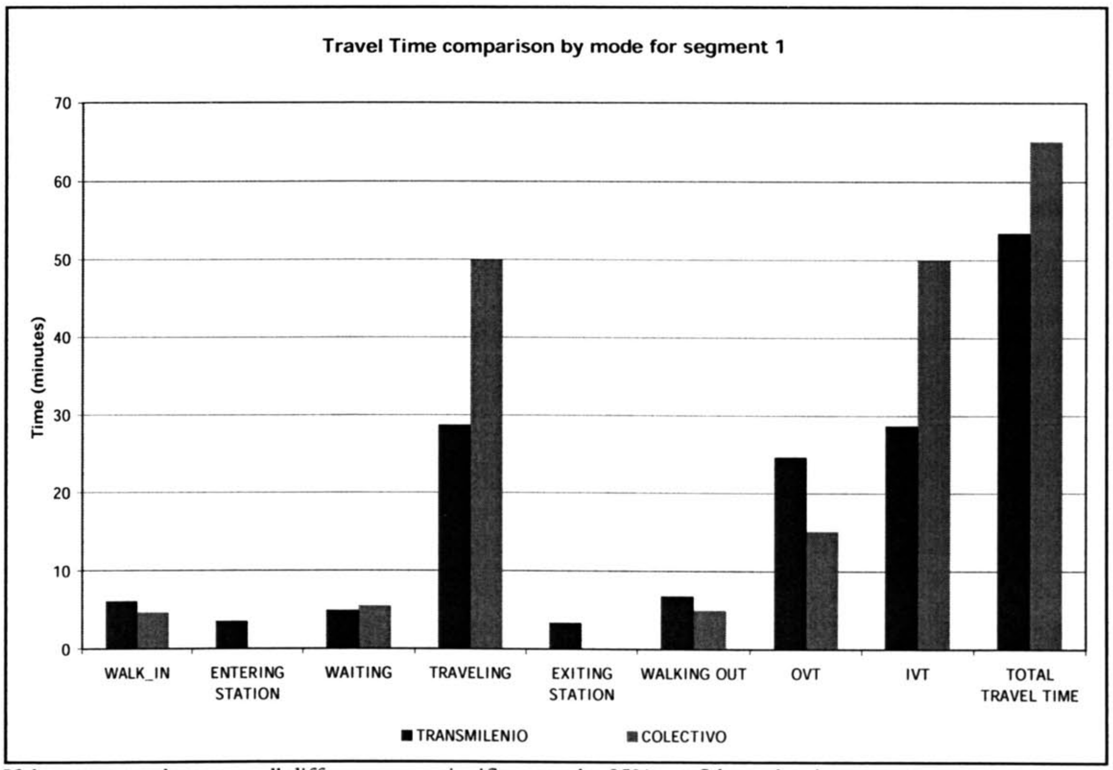
Table 5-3 Attributes of Traditional System by Market Segment

Variable	Market Segment 1		Market Segment 2	
	Mean	Standard Deviation	Mean	Standard Deviation
Market Share	0.34	-	0.30	-
Walking to Bus Stop (min)	4.65	2.81	4.51	2.48
Purchasing ticket and entering station (min)	-	-	-	-
Waiting Time (min)	5.47	3.01	5.83	3.24
In-Vehicle-Travel Time (min)	49.93	24.48	51.51	23.37
Exiting Station (min)	-	-	-	-
Walking to final destination (min)	4.98	3.38	5.38	4.59
Total Travel Time (min)	65.03	25.35	67.24	24.78
% In-Vehicle-Time	76.8%	-	76.6%	-
% Out-Vehicle-Time	23.2%	-	23.4%	-
Number of Transfers	0.05	0.22	0.05	0.22
Total Trip Cost (Col $ 2002) and (US$ 2002)	804 – 0.350	207.9	808.78 – 0.352	296.75
Chances of being seated	0.19	-	0.56	-

For those in the first market segment, Transmilenio users travel 12 minutes less per trip than those using the traditional system. The difference rests in the improvement of the in-vehicle travel time; however a closer look at the changes gives further insights. Some of the gains in travel time are offset by the increase in the out-of-vehicle travel time. The waiting time is roughly the same in the two systems (5 minutes), but Transmilenio utilization implies approximately 7 additional minutes from the purchasing of the ticket, entering, and exiting the bus station. By contrast, in the traditional mode, all those operations are done inside the vehicle.

The traditional system seems to be a more direct service since the access and egress time are lower than for Transmilenio. Also, the number of transfers and the cost are higher in Transmilenio. Figure 5-1 compares the different components of travel time by mode.

Figure 5-1 Travel time comparison by mode for Market Segment 1

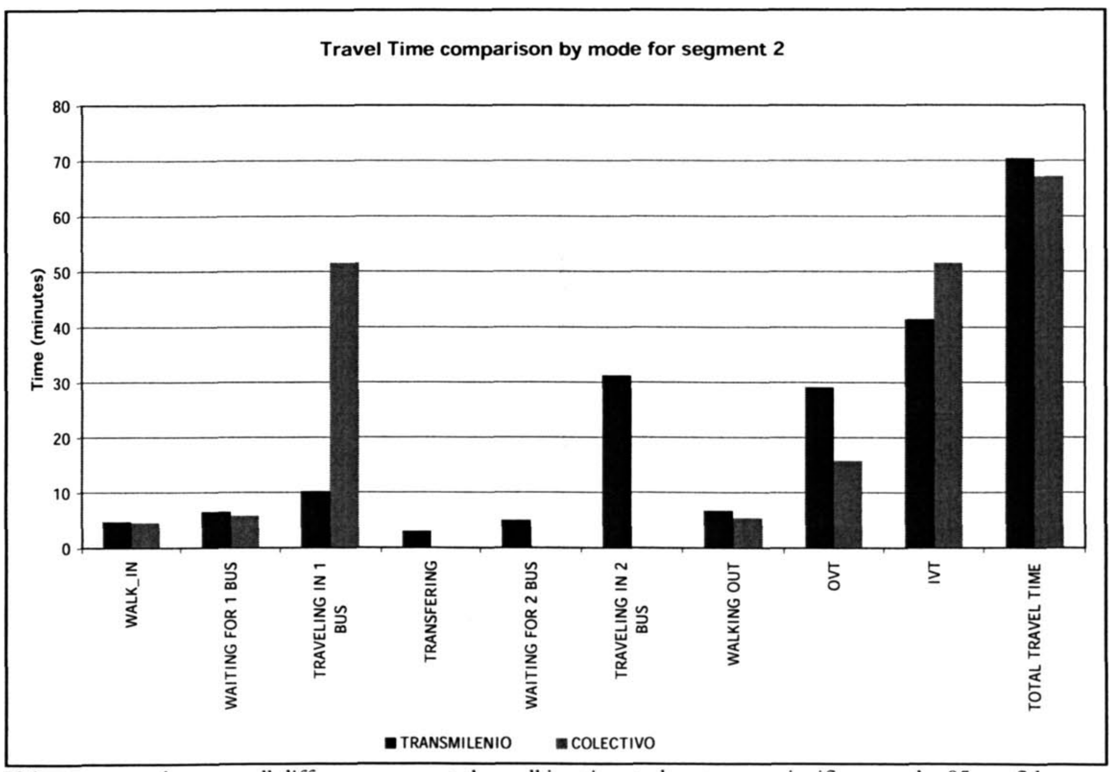


Values are sample means; all differences are significant at the 95% confidence level.

The traditional system is referred as "Colectivo".

By comparison, in the second market total travel time is 2 minutes shorter in the traditional system than in Transmilenio, the main reason being that the gains in in-vehicle-travel-time are offset by the losses in out-of-vehicle-travel time. Concerning the out-of-vehicle travel time, the walking time is roughly the same while the waiting time is slightly higher for those waiting for the Transmilenio feeder routes. In addition Transmilenio riders must spend some time (approximately 7 minutes) transferring and waiting for the trunk vehicle, and later exiting the station. The total in-vehicle-travel time (i.e., feeder + trunk bus) is lower than the in-vehicle-travel time in the traditional system. Notwithstanding this difference Transmilenio is capturing a bigger share of the market showing some preference that cannot be attributed directly to travel time modifications. Figure 5-2 presents the comparison of the different components of travel time.

Figure 5-2 Travel time comparison by mode for Market Segment 2



Values are sample mean, all differences except the walking time to bus top are significant at the 95 confidence level. The traditional system is referred as "Colectivo".

5.1 Market Segment 1

The first model was specified for all public transportation users whose trips originated in the vicinity of the trunk corridors and see Transmilenio and the traditional system as viable alternatives for their traveling needs. Firstly, a base model including only the attributes of the competing modes without controlling for socioeconomic variables was specified. For this model a test of Alternative Specific vs. Generic variables resulted in the rejection of the generic specification except for the "in-vehicle travel time" attribute. Which implies that the analytical approach that rests on the study of the alternative specific constant to understand mode preferences cannot be used in this case. Table 5-4 presents the results of the estimation.

Table 5-4 Estimation Results for the Pooled Model on Market Segment 1

Variable	Coefficient	t-statistic
CONSTANT in "Colectivo"	-3.083	-5.478
Walking in Time (c) (min)	-0.212	-5.970
Walking in Time (TM) (min)	-0.235	-8.743
Waiting Time (c) (min)	-0.084	-2.912
Waiting Time (TM) (min)	-0.102	-4.026
Fare (c) (2002 Col$)	-0.001	-1.513
Fare (TM) (2002 Col$)	-0.002	-4.648
Travel Time (min)	-0.044	-7.173
Walking out Time (c) (min)	-0.230	-7.368
Walking out Time (TM) (min)	-0.199	-10.052
Prepaid in Transmilenio	1.913	7.739
Observations	1151	
L (0)	-797.81	
L (B)	-446.27	
-2[L (0)- L (B)]	703.08	
ρ^2	0.441	
Adjusted ρ^2	0.427	

c for "Colectivo" referring to the old traditional public transportation mode

TM for Transmilenio

All variables have the correct sign and are significant at the 95% confidence level except the fare for the "colectivo", yet this variable is maintained in the model. In addition the likelihood ratio test concluded that the null hypothesis that all coefficients are equal to zero could be rejected. The number of transfers and a dummy variable representing whether the destination of the trip was located in the CBD did not turn out to be statistically significant. The alternative specific constant in the "Colectivo" utility function suggests a preference towards Transmilenio, however since most of the attributes are not generic the statement that "all else being equal" travelers would choose Transmilenio cannot be made. One still can argue that BRT attributes like safety, accessibility, or information availability, excluded from the measured attributes, could result in the negative constant for the "Colectivo" mode. In addition, the model shows that once a passenger has purchased a prepaid ticket a "commitment" to Transmilenio is formed affecting the mode decision.

A second step in the analysis looks at the trade-offs between the different attributes on each mode. These are estimated as Marginal Rates of Substitution between two attributes and are presented in Table 5-5.

Table 5-5 Trade-Offs Between Different Attributes for the Two Modes

Trade-off	Value (Col$/min)	Value (US$/hr)	t-statistic
Value of Walking in Time (c)	296.96	7.75	1.496
Value of Walking in Time (TM)	100.72	2.63	4.292
Value of Waiting Time (c)	118.20	3.08	1.345
Value of Waiting Time (TM)	43.70	1.14	3.194
Value of Travel Time (c)	62.17	1.62	1.468
Value of Travel Time (TM)	18.99	0.50	4.177
Value of Walking out Time (c)	322.86	8.42	5.197
Value of Walking out Time (TM)	84.99	2.22	4.484

c for "Colectivo" referring to the old traditional public transportation mode

TM for Transmilenio

The values are consistent with previous studies; the most recent estimation of value of travel time for Bogotá (Steer Davies Gleave, 1999) obtained from stated preference surveys, reports 1999 col$15, col$30, and col$45 per in vehicle travel time minute for low, medium, and high-income groups (1999 US$ 0.45, US$0.91, US$1.37 per hour) respectively.

They reported a factor of two when accounting for accessing time, approximately the same factor was found for waiting time in this thesis, but the factor for walking time is approximately five, which is substantially greater. All values are significant at the 80% confidence level (i.e., all are greater than 1.281); the values for Transmilenio are significant at the 99% confidence level.

In general, public transportation users assign a lower value to the time spent in Transmilenio as compared to the traditional system. For instance, one minute of waiting time in the curb can be valued at col$118.20 (US$3.08 per hour) whereas the same minute in a Transmilenio station is worth col$43.70 (US$1.14 per hour). Or, analyzed in a different way, people will be willing to pay more if they could wait one minute less in the curb in comparison with one minute in a Transmilenio station. In general, people are willing to pay more for travel savings in the traditional system; hence time in the BRT is less "painful". These differences suggest that public transportation users have changed their perception about the burden of traveling and are willing to walk longer or wait longer for BRT in comparison to the traditional system.

To conclude the analysis, point elasticites were estimated using as reference values the mean of each attribute for each mode and no prepayment of the ticket.

Table 5-6 Point Elasticities

Increase in...	**1% change Direct Elasticity** (% Change in the probability of choosing the same mode)
Transmilenio Fare	-0.67 %
Colectivo Fare	-0.40 %
Transmilenio Walk-in	-0.69 %
Colectivo Walk-in	-0.69 %
Transmilenio Waiting Time	-0.15 %
Colectivo Waiting Time	-0.32 %
Transmilenio Travel Time	-0.39 %
Colectivo Travel Time	- 1.53 %
Transmilenio Walk-Out	-0.42%
Colectivo Walk-Out	-0.79 %

Table 5-7 Point Elasticities (Continued)

Increase in...	1% change Cross Elasticity (% Change in the probability of choosing the other mode)
Transmilenio Fare	1.54 %
Colectivo Fare	0.17 %
Transmilenio Walk-in	1.58 %
Colectivo Walk-in	0.30 %
Transmilenio Waiting Time	0.35 %
Colectivo Waiting Time	0.14 %
Transmilenio Travel Time	0.90 %
Colectivo Travel Time	0.67 %
Transmilenio Walk-Out	0.96 %
Colectivo Walk-Out	0.34 %

Assuming that modal share is equivalent to probability (this is the case here because the model does not control for socioeconomic characteristics of taste variations and therefore the sum over all users equal the probability), the demand for both modes was found to be inelastic to changes in its attributes in all cases but in the "Colectivo" in-vehicle travel time. That is, an increase of 1% in the in-vehicle travel time by "Colectivo" results in a drop of 1.53% in the probability of choosing that mode. By contrast, an examination of cross-elasticites reveals that the probability of choosing "Colectivo" will increase by 1.54% if Transmilenio fare increases by 1% and by 1.58% if the walking time to Transmilenio increases by the same amount, those effects correspond to the greater direct-elasticities. In all other cases, cross-elasticities are less than one. Hence, the demand for Transmilenio is more elastic to changes in the fare and in the waking time, while the demand for the traditional system is more sensitive to in-vehicle travel time.

So far, no socioeconomic characteristics or taste variations have been analyzed, in order to conclude that the improvements have occurred one must control for those variables; the next sections deal with that issue. In this regards the following three sub market segments were analyzed:

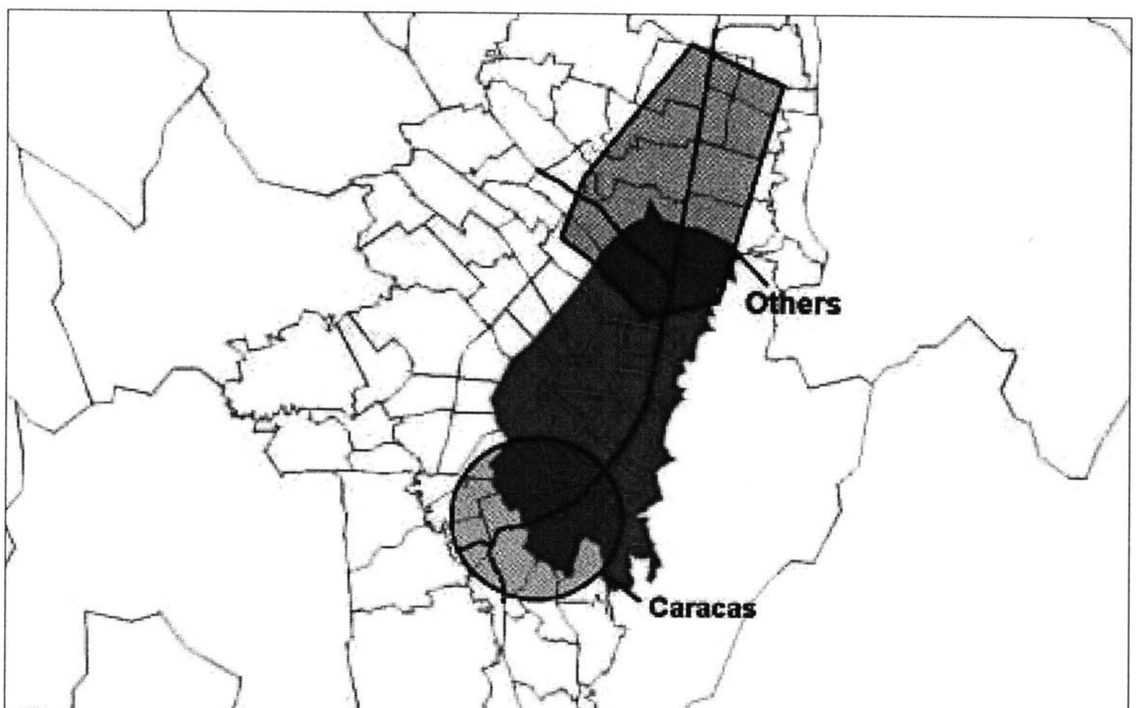
a) Segmentation by area of influence (i.e., location in the city)
b) Segmentation by wealth

c) Segmentation by opportunity cost of the trip

5.1.1 Sub-Market 1: By Area of Influence

The underlying hypothesis is that the location of the origin of the trip influences traveler's behavior. It rests on the fact that the urban environment is rather different in the two selected areas. Figure 5-3 presents the geographical distribution of the sub markets. One group consists of those that start their trip in the southern branch of the "Troncal Caracas". The second group is comprised of travelers starting their trips on the northern branch of the system, namely, close to "Calle 80" or "Autopista Norte". The main statistics describing the travelers are presented in Table 5-8, Table 5-9, and Table 5-10. In general, people living on the first area have lower income levels and car ownership rate. In addition, urban design in the first area is typically considered poorer, hence walking and waiting in that area are seen as more distasteful that in the latter area. The a-priori considerations are partially confirmed by the descriptive statistics presented in the corresponding tables.

Figure 5-3 Geographical Distribution of sub-markets in Market 1



The colored zone represents the extended city center, and the lines show the existing Transmilenio exclusive lanes.

Table 5-8 Characteristics of Travelers in Market Segment 1 by Area of Influence

Variable	Caracas Avenue		Other Areas	
	Mean	Standard Deviation	Mean	Standard Deviation
To Work	0.55	-	0.56	-
To CBD	0.59	-	0.60	-
Travel Alone	0.88	-	0.90	-
Prepaid Transmilenio	0.27	-	0.25	-
Need to be in destination on time	0.79	-	0.81	-
Weekly frequency of travel	4.51	1.48	4.59	1.42
Male	0.60	-	0.57	-
Female	0.40	-	0.43	-
Access to car in households	0.10	-	0.15	-
Live in own house	0.62	-	0.63	-
Receive wages and salaries	0.75	-	0.74	-
Married	0.53	-	0.52	-
Stratum 1 or 2 (Proxy for low income level)	0.53	-	0.36	-
Stratum 3 (Proxy for medium income level)	0.38	-	0.50	-
Stratum 4 or 5 or 6 (Proxy for high income)	0.09	-	0.14	-
Years of Education	12.06	3.06	12.55	3.17

Table 5-9 Attributes of Transmilenio by Proximity to Specific Corridor in Market Segment 1 by Area of Influence

Variable	Caracas Avenue		Other Areas	
	Mean	Standard Deviation	Mean	Standard Deviation
Market Share	0.67	-	0.57	-
Walking to Transmilenio Station (min)	5.98	3.50	6.78	3.80
Purchasing ticket and entering station (min)	3.48	2.19	3.56	2.14
Waiting Time (min)	4.96	2.12	4.90	2.12
In-Vehicle-Travel Time (min)	28.35	14.22	28.53	13.78
Exiting Station (min)	3.33	2.12	3.38	1.94
Walking to final destination (min)	6.73	4.32	7.00	4.96
Total Travel Time (min)	52.85	16.38	54.18	17.24
% In-Vehicle-Time	53.6 %	-	52.6 %	-
% Out-Vehicle-Time	46.4 %	-	47.4 %	-
Number of Transfers	0.11	0.35	1.11	0.33
Total Trip Cost (Col $ 2002) and (US$ 2002)	938.13 – 0.408	178.8	966.19 - 0.420	228.00
Chances of being seated	0.16	-	0.08	-

Table 5-10 Attributes of Traditional System by Proximity to Specific Corridor in Market Segment 1 by Area of Influence

Variable	Caracas Avenue		Other Areas	
	Mean	Standard Deviation	Mean	Standard Deviation
Market Share	0.33	-	0.43	-
Walking to Bus Stop (min)	4.61	2.79	4.83	2.89
Purchasing ticket and entering station (min)	-	-	-	-
Waiting Time (min)	5.50	2.98	5.58	3.35
In-Vehicle-Travel Time (min)	49.44	24.94	51.19	24.39
Exiting Station (min)	-	-	-	-
Walking to final destination (min)	5.06	3.41	4.50	3.00
Total Travel Time (min)	64.62	25.87	66.18	25.12
% In-Vehicle-Time	76.5%	-	77.4%	-
% Out-Vehicle-Time	23.5%	-	22.6%	-
Number of Transfers	0.05	0.21	0.05	0.22
Total Trip Cost (Col $ 2002) and (US$ 2002)	801.7 – 0.349	205.1	821.96 – 0.357	226.17
Chances of being seated	0.19	-	0.20	-

Two models, one for each sub market, were specified following the structure of the pooled mode for Market 1 (Table 5-4). The corresponding Likelihood Ratio test rejects the null hypothesis that there is no taste variation across different areas of the city. The corresponding coefficients for the two models are presented in Table 5-11. All the signs are correct in the two models, however, the fare, the waiting time, and the alternative specific constant for the "colectivo" mode turned out to be not significant. Notwithstanding, they are all kept in the model because the lack of significance can be attributed to the poor variability in the data confirming one of the drawbacks of RP surveys.

In the Transmilenio case, most of the coefficients are significant and show that despite lower incomes in the southern branch of Caracas Av., the values of time are higher with the exception of the walking time to the station. The values of in-vehicle travel time are very similar but the waiting and the walking-out time are rather different. Currently people are willing to wait and walk longer to the final destination for those trips originating in corridors others than Caracas Avenue. By contrast, users starting the trip in the vicinity of Caracas are willing to walk longer to get to the BRT stop despite a poorer urban design. It is not possible to conclude that Transmilenio is on a better position to compete on a specific region.

Table 5-11 Estimation Results Market Segment 1 by Area of Influence

	Caracas Avenue		Other Areas	
Variable	Coefficient	t-statistic	Coefficient	t-statistic
CONSTANT in colectivo	-2.6477	-2.9282	-1.1852	-1.433
Walking in Time (c) (min)	-0.2618	-4.9290	-0.1519	-2.799
Walking in Time (TM) (min)	-0.1898	-4.6672	-0.1993	-5.009
Waiting Time (c) (min)	-0.1846	-3.2780	-0.0712	-2.044
Waiting Time (TM) (min)	-0.1770	-5.1604	-0.0487	-1.066
Fare (c) (Col $ 2002)	-0.0008	-0.9456	-0.0006	-0.991
Fare (TM) (Col $ 2002)	-0.0018	-1.9975	-0.0016	-2.571
Travel Time (min)	-0.0524	-5.6867	-0.0427	-4.472
Walking out Time (c) (min)	-0.2284	-5.2517	-0.1994	-4.198
Walking out Time (TM) (min)	-0.2137	-7.8006	-0.1565	-4.960
Prepaid in Transmilenio	1.8563	5.4614	2.0967	5.535
Observations	764		387	
L (0)	-529.56		-268.25	
L (B)	-248.44		-170.66	
-2[L (0)- L (B)]	562.24		195.18	
ρ^2	0.539		0.363	
Adjusted ρ^2	0.511		0.323	

Table 5-12 Trade-Offs Between Different Attributes for the Two Modes in Market Segment 1 by Area of Influence

	Caracas		Others	
Trade-off	Value (Col$/min) and (US$/hr)	t-statistic	Value ($/min) (Col$/min) and (US$/hr)	t-statistic
Value of Walking in Time (c)	319.58 – 8.34	0.926	261.17 – 6.81	0.982
Value of Walking in Time (TM)	105.30 – 2.75	1.912	122.00 – 3.18	2.386
Value of Waiting Time (c)	225.40 – 5.88	0.912	122.31 – 3.19	0.886
Value of Waiting Time (TM)	98.19 – 2.56	1.827	29.81 – 0.78	1.046
Value of Travel Time (c)	64.03 – 1.67	0.916	73.35 – 1.91	0.974
Value of Travel Time (TM)	29.10 – 0.76	1.891	26.12 – 0.68	2.483
Value of Walking out Time (c)	278.79 - 7.27	0.943	342.84 – 8,94	0.964
Value of Walking out Time (TM)	118.54 – 3.09	1.970	95.80 – 2.50	2.429

Regardless of location in the city, the values of time for Transmilenio are lower than for the traditional system; however, neither the market segmentation nor the model specification account for the constraints conditioning value of time. These will be addressed in the analysis of the following two sub markets.

5.1.2 Sub Market 2: By Wealth

Transportation discrete choice models usually find that income level is a significant factor of variations of market taste. Hence, proving the hypothesis about the difference in the marginal rates of substitution resulting from the improvement of the service requires controlling for budget constraints. Following the advice of some of the planners in Transmilenio, the survey did not ask the income level instead a strategy to capture proxies for the same variable was adopted. These variables are the socioeconomic strata classification used for taxation purposes, the years of formal education, whether the household has access to a vehicle, and status of home ownership. After checking a correlation matrix between these variables, the following rule was established to approach the segmentation by wealth:

- High Level of Wealth: (stratum4 or stratum 5 or stratum 6) or (Years of Education >12)
- Low Level of Wealth: (Years of Education <13) and (stratum 1 or stratum 2)

The comparison of the two segments cannot be made on the basis of the segmentation criteria; therefore the wealth difference has to be confirmed on other variables. These are presented in Table 5-13; for instance access to car is higher in the High Income level (0.15 vs. 0.09), and the geographical distribution corresponds to the perceived income distribution, that is, people living in Caracas typically have a lower income level than those in the other two sectors. In addition house ownership rates and proportion of female travelers are higher for the High Income level. In conclusion, the use of the proxies appears to have worked for the desired segmentation.

Table 5-13 Characteristics of Travelers in Market Segment 1 by Level of Wealth

Variable	High Wealth		Low Wealth	
	Mean	Standard Deviation	Mean	Standard Deviation
In Calle 80	0.23	-	0.14	-
In Autopista Norte	0.30	-	0.05	-
In Caracas	0.48	-	0.81	-
To Work	0.53	-	0.57	-
To CBD	0.62	-	0.62	-
Travel Alone	0.90	-	0.87	-
Prepaid Transmilenio	0.28	-	0.26	-
Need to be in destination on time	0.84	-	0.76	-
Weekly frequency of travel	4.61	1.38	4.48	1.55
Male	0.53	-	0.64	-
Female	0.47	-	0.36	-
Access to car in households	0.15	-	0.09	-
Live in own house	0.67	-	0.57	-
Receive wages and salaries	0.76	-	0.74	-
Married	0.50	-	0.54	-
Stratum 1 or 2 (Proxy for low income level)	0.32	-	0.60	-
Stratum 3 (Proxy for medium income level)	0.49	-	0.40	-
Stratum 4 or 5 or 6 (Proxy for high income)	0.19	-	0.00	-
Years of Education	14.73	2.47	10.912	1.60

Some of the travel indicators (Table 5-14) further confirm the segmentation; for example, on average travelers on the high level of wealth pay more than those in the low-wealth segment. Interestingly however, the market share of the traditional system is higher in the high-wealth segment. This could result from the redistribution of routes after the new system was in place and the fact that in the south there may be fewer alternatives. It is important to acknowledge that the presence in the survey of people belonging to the upper income levels in the city is very scarce, in theory they are not users of either one of the alternatives. The low rates of household car ownership further confirm this view.

As in the previous case, two models were estimated following the specification of the pooled data for market 1. The corresponding Likelihood Ratio test rejects the null hypothesis that there is no taste variation across different levels of income. The corresponding coefficients for the two models are presented in Table 5-16.

Table 5-14 Attributes of Transmilenio in Market Segment 1 by Level of Wealth

Variable	High Wealth		Low Wealth	
	Mean	Standard Deviation	Mean	Standard Deviation
Market Share	0.55	-	0.74	-
Walking to Transmilenio Station (min)	6.79	3.75	5.60	3.32
Purchasing ticket and entering station (min)	3.58	2.31	3.45	2.09
Waiting Time (min)	4.89	2.13	4.94	2.19
In-Vehicle-Travel Time (min)	29.20	13.34	28.36	14.53
Exiting Station (min)	3.31	1.50	3.37	2.46
Walking to final destination (min)	7.39	5.31	6.34	3.79
Total Travel Time (min)	55.16	16.42	52.05	16.32
% In-Vehicle-Time	52.9 %	-	54.5 %	-
% Out-Vehicle-Time	47.1 %	-	45.5 %	-
Number of Transfers	0.11	0.33	0.12	0.37
Total Trip Cost (Col \$ 2002) and (US\$ 2002)	949.21 – 0.413	202.08	940.96- 0.409	178.85
Chances of being seated	0.08	-	0.20	-

Table 5-15 Attributes of Traditional System by Market Segment by Level of Wealth

Variable	High Wealth		Low Wealth	
	Mean	Standard Deviation	Mean	Standard Deviation
Market Share	0.45	-	0.26	-
Walking to Bus Stop (min)	4.45	2.53	4.81	3.00
Purchasing ticket and entering station (min)	-	-	-	-
Waiting Time (min)	5.37	2.82	5.55	3.15
In-Vehicle-Travel Time (min)	50.36	21.72	49.60	26.44
Exiting Station (min)	-	-	-	-
Walking to final destination (min)	4.61	3.19	5.27	3.50
Total Travel Time (min)	64.79	22.98	65.22	27.07
% In-Vehicle-Time	77.7%	-	76.0%	-
% Out-Vehicle-Time	22.3%	-	24.0%	-
Number of Transfers	0.07	0.25	0.04	0.19
Total Trip Cost (Col \$ 2002) and (US\$ 2002)	819.25 - 0.356	233.66	792.12 – 0.344	184.79
Chances of being seated	0.19	-	0.19	-

Table 5-16 Estimation results by wealth on Market Segment 1 by Level of Wealth

	Higher Level of Wealth		Lower Level of Wealth	
Variable	Coefficient	t-statistic	Coefficient	t-statistic
CONSTANT in colectivo	-4.5577	-4.5699	-2.2707	-2.9801
Walking in Time (c) (min)	-0.1227	-2.1231	-0.2292	-4.7565
Walking in Time (TM) (min)	-0.2668	-6.6992	-0.1805	-4.5675
Waiting Time (c) (min)	-0.0839	-1.6903	-0.0828	-2.1703
Waiting Time (TM) (min)	-0.1006	-2.3306	-0.1292	-3.7982
Fare (c) (Col $ 2002)	-0.0004	-0.6593	-0.0014	-1.6968
Fare (TM) (Col $ 2002)	-0.0025	-3.1651	-0.0027	-3.5283
Travel Time (min)	-0.0381	-4.3958	-0.0572	-6.2697
Walking out Time (c) (min)	-0.2274	-4.5859	-0.2182	-5.1325
Walking out Time (TM) (min)	-0.2713	-8.2996	-0.1476	-5.8004
Prepaid in Transmilenio	1.8723	5.4887	2.2220	5.4321
Observations	504		647	
L (0)	-349.35		-448.47	
L (B)	-185.74		-239.05	
-2[L (0)- L (B)]	327.22		418.84	
ρ^2	0.468		0.467	
Adjusted ρ^2	0.437		0.442	

The signs of the coefficients are correct and most of them are significant at the 95% confidence level. The coefficient for the fare of the traditional system is not significant for the higher level of wealth; however it will be kept in the model. As mentioned earlier the most probable reason is the lack of variability associated with RP surveys. Interestingly, the alternative specific constant for the higher wealth level is the greatest off all the studied models. In addition, for people on the lower wealth level, having a prepaid Transmilenio ticket has a stronger influence on the mode decision than in the case of the higher income level. A study of the other coefficients does not reveal a clear pattern in terms of the competition between the two modes. The analysis over the marginal rates of substitution provides further insight to the comparative analysis.

Table 5-17 Trade-Offs Between Different Attributes for the Two Modes in Market Segment 1 by Level of Wealth

Trade-off	Higher Wealth Value (Col$/min) and (US$/hr)	Higher Wealth t - statistic	Lower Wealth Value (Col$/min) and (US$/hr)	Lower Wealth t - statistic
Value of Walking in Time (c)	283.82 – 7.40	0.652	163.94 – 4.28	1.600
Value of Walking in Time (TM)	108.83 – 2.84	2.957	67.63 – 1.76	2.953
Value of Waiting Time (c)	193.99 – 5.06	0.609	59.23 –1.55	1.336
Value of Waiting Time (TM)	41.03 – 1.07	2.126	48.42 – 1.26	2.590
Value of Travel Time (c)	88.07 – 2.30	0.650	40.88 – 1.07	1.635
Value of Travel Time (TM)	15.53 – 0.41	2.816	21.42 – 0.56	3.265
Value of Walking out Time (c)	526.05 –13.72	0.652	156.05 – 4.07	1.669
Value of Walking out Time (TM)	110.67 – 2.89	3.176	55.32 –1.44	3.154

Despite the lack of significance of some rates of substitution, the analysis shows that they are consistently lower than for the traditional system. In addition, and in accordance with the results of many discrete choice models, the value of time for the higher wealth segment is greater than for the lower one. Only in the case of in-vehicle travel time the valuation is higher for the lower income group. In conclusion, controlling for wealth, which serves as a proxy for the budget constraint, values of time for Transmilenio are lower than for the traditional system.

The difference in the valuation of time is greater for the traditional system than for Transmilenio. That is, when traveling in the BRT, people tend to value time more similarly regardless of income level as opposed to the buses in mixed traffic where the difference is greater.

5.1.3 Sub Market 3: By Opportunity Cost of the Trip

The last market segmentation is meant to control for the opportunity cost of making the trip. The segmentation variable in this case is the trip purpose, it is assumed that "trips to work" have a higher opportunity cost and therefore the corresponding values of time should be higher regardless of mode. If controlling for this variable, the marginal rates of substitution are still higher for the traditional mode than for Transmilenio, then we can conclude that improvements have indeed been realized. Table 5-18 presents the characteristic of the travelers by market segment.

Table 5-18 Characteristics of Travelers in Market Segment 1 by Opportunity Cost of the Trip

Variable	High Opportunity Cost		Low Opportunity Cost	
	Mean	Standard Deviation	Mean	Standard Deviation
In Calle 80	0.18	-	0.17	-
In Autopista Norte	0.14	-	0.18	-
In Caracas	0.67	-	0.65	-
To CBD	0.59	-	0.65	-
Travel Alone	0.96	-	0.79	-
Prepaid Transmilenio	0.29	-	0.24	-
Need to be in destination on time	0.85	-	0.73	-
Weekly frequency of travel	5.24	0.92	3.67	1.57
Male	0.64	-	0.53	-
Female	0.36	-	0.47	-
Access to car in households	0.11	-	0.13	-
Live in own house	0.66	-	0.56	-
Receive wages and salaries	0.96	-	0.49	-
Married	0.65	-	0.37	-
Stratum 1 or 2 (Proxy for low income level)	0.49	-	0.46	-
Stratum 3 (Proxy for medium income level)	0.44	-	0.44	-
Stratum 4 or 5 or 6 (Proxy for high income)	0.07	-	0.11	-
Years of Education	12.21	3.26	12.05	2.78

One can argue that the proxy is appropriate insofar as trips in the high-opportunity – cost segment are done more frequently, are typically done by workers, by a larger proportion of males, and for people that need to be on destination on time. On the contrary, travelers doing low-opportunity cost do not receive wages or salaries, need to be on time at destination in a lower proportion, female travelers are more common, and the trip is done with less frequency. In addition, Table 5-19 and Table 5-20, show that high-opportunity cost usually takes longer than low-opportunity cost, which may imply that they are done on the peak hours, the difference is larger in the in-vehicle travel time confirming this view.

Table 5-19 Attributes of Transmilenio in Market Segment 1 by Opportunity Cost of the Trip

Variable	High Opportunity Cost		Low Opportunity Cost	
	Mean	Standard Deviation	Mean	Standard Deviation
Market Share	0.69	-	0.62	-
Walking to Transmilenio Station (min)	6.12	3.55	6.11	3.59
Purchasing ticket and entering station (min)	3.41	1.97	3.62	2.43
Waiting Time (min)	4.95	2.15	4.88	2.18
In-Vehicle-Travel Time (min)	30.13	14.78	27.00	12.84
Exiting Station (min)	3.36	2.20	3.33	1.97
Walking to final destination (min)	6.70	4.62	6.92	4.46
Total Travel Time (min)	54.67	16.42	51.85	15.60
% In-Vehicle-Time	55.1 %	-	52.0 %	-
% Out-Vehicle-Time	44.9 %	-	48.0 %	-
Number of Transfers	0.13	0.33	0.09	0.31
Total Trip Cost (Col $ 2002) and (US$ 2002)	940.16 – 0.409	202.08	950.00 – 0.413	207.01
Chances of being seated	0.15	-	0.14	-

Table 5-20 Attributes of Traditional System in Market Segment 1 by Opportunity Cost of the Trip

Variable	High Opportunity Cost		Low Opportunity Cost	
	Mean	Standard Deviation	Mean	Standard Deviation
Market Share	0.31	-	0.38	-
Walking to Bus Stop (min)	4.77	2.85	4.50	2.75
Purchasing ticket and entering station (min)	-	-	-	-
Waiting Time (min)	5.38	2.95	5.58	3.09
In-Vehicle-Travel Time (min)	51.98	24.37	47.41	24.40
Exiting Station (min)	-	-	-	-
Walking to final destination (min)	5.10	3.38	4.82	3.39
Total Travel Time (min)	67.24	25.23	62.31	25.26
% In-Vehicle-Time	77.3%	-	76.0%	-
% Out-Vehicle-Time	22.7%	-	24.0%	-
Number of Transfers	0.06	0.25	0.03	0.18
Total Trip Cost (Col $ 2002) and (US$ 2002)	805.67 – 0.350	200.88	801.94 – 0.349	216.52
Chances of being seated	0.19	-	0.20	-

As in the previous cases, two models were specified and the corresponding Likelihood Ratio test rejects the null hypothesis that there is no taste variation across trip opportunity cost.

Table 5-21 Estimation results for model in Market Segment 1 by Opportunity Cost of the Trip

	High Opportunity Cost		Low Opportunity Cost	
Variable	**Coefficient**	**t-statistic**	**Coefficient**	**t-statistic**
CONSTANT in colectivo	-5.2986	-5.7866	-1.8727	-2.5277
Walking in Time (c) (min)	-0.2051	-4.1867	-0.2252	-4.1847
Walking in Time (TM) (min)	-0.2498	-6.6324	-0.2293	-5.6816
Waiting Time (c) (min)	-0.0649	-1.6699	-0.0946	-2.2373
Waiting Time (TM) (min)	-0.1115	-2.9860	-0.1049	-2.8885
Fare (c) (Col $ 2002)	-0.0002	-0.2503	-0.0008	-1.1435
Fare (TM) (Col $ 2002)	-0.0037	-5.1429	-0.0013	-1.8326
Travel Time (min)	-0.0458	-5.1544	-0.0462	-5.0312
Walking out Time (c) (min)	-0.2404	-5.1250	-0.2129	-4.9351
Walking out Time (TM) (min)	-0.2227	-7.1426	-0.1882	-7.1290
Prepaid in Transmilenio	2.8956	6.3139	1.2517	3.9653
Observations	635		516	
L (0)	-440.15		-357.66	
L (B)	-217.06		-217.94	
-2[L (0)- L (B)]	446.18		279.44	
ρ^2	0.507		0.391	
Adjusted ρ^2	0.482		0.360	

Although the signs are correct and the likelihood ratio test concluded that the null hypothesis, that all coefficients equal to zero, could be rejected, the t-statistic for the coefficient of the fare in the traditional system is very low. Furthermore, when analyzing the confidence interval the negative sign is not statistically significant. In turn this implies that the values of time are not significant. The model specification is troublesome and responds to the drawbacks of RP data. Nonetheless, the corresponding marginal rates of substitution are provided in Table 5-22. Although the values for Transmilenio are typically lower than for the traditional system, the difference between the high opportunity and the low opportunity cost does not coincide with the hypothesis and the conventional approach. What they imply is that people will be willing to pay more for improvements in their low-opportunity-cost trips in comparison to their high-opportunity-cost trips. This would occur if service during the peak hour (presumably when most of the high-opportunity cost trips are done) would be very different from the non-peak hour. However, from the average values given in Table 5-19 and Table 5-20 this does not seem to be the case.

Table 5-22 Trade-Offs Between Different Attributes for the Two Modes in Market Segment 1 by Opportunity Cost of the Trip

Trade-off	High Opportunity Cost		Low Opportunity Cost	
	Value (Col$/min) and (US$/hr)	t - statistic	Value (Col$/min) and (US$/hr)	t - statistic
Value of Walking in Time (c)	1,204.35 – 31.42	0.251	288.48 – 7.53	1.114
Value of Walking in Time (TM)	67.99 – 1.77	4.473	170.02 – 4.44	1.765
Value of Waiting Time (c)	380.95 – 9.94	0.249	121.27 – 3.16	1.019
Value of Waiting Time (TM)	30.35 – 0.79	2.673	77.80 – 2.03	1.775
Value of Travel Time (c)	268.83 – 7.01	0.249	59.21 – 1.54	1.101
Value of Travel Time (TM)	12.46 – 0.33	4.118	34.27 – 0.89	1.775
Value of Walking out Time (c)	1,411.12 – 36.81	0.250	272.78 – 7.12	1.122
Value of Walking out Time (TM)	60.62 –1.58	4.615	139.56 – 3.64	1.828

Despite the problems raised by the analysis of the last sub market, the overall result of the study of the trips that start in the vicinity of the exclusive bus lane corridors show that improvements in travel time have been realized. Differences in the average travel times consistently demonstrate this statement, but the study of the value of time reinforces this view from a microeconomic perspective. This situation holds when controlling for area of the city and budgetary constraints. When controlling for opportunity cost of the trip, the analysis is inconclusive.

In general, people are willing to spend more time in Transmilenio than in the traditional system even when paying a higher fare for the former. Underlying this behavior is the quality of the service of the BRT, which makes the time spent in this mode less burdensome.

5.2 Market Segment 2

Adopting the same specification used for the Market Segment 1, a model was specified for those trips starting in the areas where the Transmilenio feeder routes run in competition with routes from the traditional system. As shown in Table 5-1, Table 5-2, and Table 5-3 this segment is characterized by a lower income level and by higher travel times. Comparing the modes by travel time, Transmilenio is only a better option in the first market segments; in the market analyzed in this section, the traditional system is approximately 1 minute faster. Despite this fact, Transmilenio captures a bigger market share. Unfortunately, the results of the model estimation in this segment are rather poor to conduct a thorough study of this situation. However, it confirms that Transmilenio users perceive a lower value of time than users of the traditional mode.

As shown in Table 5-23 , the signs of the coefficients correspond to the hypotheses but the t-statistics for the fare variable are low, in particular for the traditional mode. In consequence, the respective marginal rates of substitution are not significant and the comparison is troublesome; these are presented in Table 5-24. Nonetheless, the comparison between the two modes is consistent with previous findings; the rates for Transmilenio are lower than for the traditional mode, as mentioned earlier, the low t-statistics prevent a more conclusive statement.

A comparison of the models representing the two markets (i.e., Market Segment 1 vs. Market Segment 2) suggest that marginal rates of substitution are greater in the second market and consistently the travelers subject to longer travel times (Market Segment 2, or Ring 2) are willing to pay more for improvements than those traveling less (Market Segment 1 or Ring 1). One can only understand this situation by saying that those users that access Transmilenio by foot are willing to walk, wait, and travel longer than those that access it by feeder routes. The difference between the two modes is in this case, as previously, greater for the traditional mode than for Transmilenio.

Table 5-23 Estimation results on Market Segment 2

Variable	Coefficient	t-statistic
CONSTANT in "Colectivo"	-1.020	-1.9642
Walking in Time (c) (min)	-0.131	-2.9268
Walking in Time (TM) (min)	-0.124	-3.1549
Waiting Time (c) (min)	-0.114	-3.7411
Waiting Time (TM) (min)	-0.031	-2.1336
Fare (c) (Col $ 2002)	-0.00002	-0.5289
Fare (TM) (Col $ 2002)	-0.001	-1.2129
Travel Time (min)	-0.028	-5.5356
Walking out Time (c) (min)	-0.106	-4.5917
Walking out Time (TM) (min)	-0.098	-5.6303
Prepaid in Transmilenio	1.483	6.4645
Observations	945	
L (0)	-655.02	
L (B)	-479.05	
-2[L (0)- L (B)]	351.04	
ρ^2	0.268	
Adjusted ρ^2	0.251	

Table 5-24 Trade-Offs Between Different Attributes for the Two Modes in Market Segment 2

Trade-off	Value ($/min)	Value (US$/hr)	t- statistics
Value of Walking in Time (c)	709.58	18.51	0.525
Value of Walking in Time (TM)	205.15	5.35	1.151
Value of Waiting Time (c)	615.89	16.07	0.528
Value of Waiting Time (TM)	50.89	1.33	1.068
Value of Travel Time (c)	150.05	3.91	0.526
Value of Travel Time (TM)	45.70	1.19	1.179
Value of Walking out Time (c)	576.14	15.03	0.522
Value of Walking out Time (TM)	162.29	4.23	1.172

5.3 Conclusion

The hypothesis that the introduction of Transmilenio results in the improvement of the traveling conditions is supported by the analysis presented in this chapter. Consistently, all specified models suggest that traveling conditions have been enhanced. In consequence, the amount that travelers in the traditional system are willing to pay for time savings is, in general, greater than what people are willing to pay for further savings in Transmilenio. In consequence, Transmilenio users are willing to walk and wait longer than users of the buses in mixed traffic.

As suggested by the examination of the governing relationships of travel behavior in Bogotá, people living in the outer ring are subject to worst traveling conditions. The comparative analysis of the two market segments, despite some issues with the significance of some coefficients, reached a similar conclusion. The marginal rates of substitution provide evidence to support that the improvements have been greater for the people in the city center and the first ring as compared to people in the outer ring. These are located in areas where the feeder routes compete with routes from the traditional system. In these areas Transmilenio is less competitive in terms of travel time, however still captures a greater share of the market reinforcing the lower valuation of time and suggesting that BRT offers additional attributes that are valued by the riders.

This analysis suggests that BRT is perceived very differently from the traditional buses operating in mixed traffic. From the perspective of travel behavior, Transmilenio is seen as a superior mode and a bimodal public transportation network has been created. This last element is the center of the political and economic consequences as presented in the next chapter.

6 Conclusions: Impacts on travel behavior and its consequences

It is almost tantamount to say that the introduction of a new, and presumably better, public transportation mode induces changes in travel behavior. Verifying that the changes are occurring is relevant but what matters the most is what these changes entail, thus far this document has dealt with the first part; this final chapter looks at the emerging implications. First I recapitulate the main findings of the previous chapters highlighting the research questions and later I answer them, issue policy recommendations or further research opportunities where appropriate.

6.1 Summary of Main Findings and Research Questions

This study began by describing the introduction of a new and "better" public transportation system in Bogotá in the context of an existing poor level of service and high levels of transit captivity. The new system entailed an improvement of the level of service and a transformation of the existing travel behavior. Implicitly, these assumptions built upon the principles that motivated the creation of Transmilenio in the first place, the rather obvious better service vis-à-vis the existing buses, and the anecdotic evidence suggesting that some car users have actually shifted to transit.

Provided this starting point, this work examined the existing relationships governing travel behavior before the new BRT system was introduced. The main finding in this regard was that disparities in travel time and trip rates existed between car and transit users. It showed that given a fixed level of public transportation, access to private automobile induced lower total daily travel time and higher trip rates. The main cause of access to the private automobile was the level of wealth. However wealth was not the sole origin of the disparities, in addition, the uneven distribution of jobs and population aggravated this effect as people living far from the Central Business District were subject to higher inequalities regardless of mode choice. Finally, the analysis suggested that a better public transportation system will contribute in shrinking the gap between car and transit. Thus far, the examination confirmed what is commonly expected from a city like Bogotá, yet it created the stage for the first two research questions that this thesis was meant to explore: What are the determinants of public transport mode choice? and subsequently, To what extent has Transmilenio modified the existing travel behavior?

To understand these changes, this study turned its attention to the public transportation users, in particular to the way Transmilenio and the existing bus service are perceived as competing modes. These people are the ones accruing most of the benefits and comprising the majority of the population, a detailed study of their behavior was conducted. By contrast, an evaluation of auto users was not possible due to lack of data but it is a natural follow-up and would shed some light over the possibility of auto drivers shifting to transit. Therefore, this issue was only partially addressed and the findings in this regard are speculative above all.

The study of the behavior of transit users demonstrated the main hypothesis accompanying the introduction of the new mode. In fact, Transmilenio is offering a better level of service than the traditional system. There is evidence suggesting that improvements, mostly in in-vehicle travel time have occurred. In particular, the value of time (i.e., the marginal rate of substitution between time and money), which is lower for the BRT, indicates that traveling in the new mode is less distasteful than in the previously existing buses. This examination provided the grounds for the third research questions namely: Are changes in travel behavior uniformly distributed among all public transportation users?

The behavioral changes found in this thesis need to be seen in a broader way and embedded in the newly created organizational and institutional setting. This perspective give rise to the last research question: What are the challenges and opportunities that the new institutional arrangement will face given the prevailing travel behavior?

6.2 What are the determinants of the choice between the two public transportation modes?

The study of the competition between the two public transport modes (i.e., BRT – Transmilenio vs. Buses in mixed traffic – Traditional system) resulted in the following determinants of the public transport mode choice process:

- Time spent in Transmilenio is less distasteful than time spent in the traditional mode.
- Transmilenio's advantage based on lower travel time diminishes as the user distances from the trunk corridors while its advantage based on other attributes, (i.e., safety, reliability, security, etc.) increases.
- Regardless of mode, walking time is valued higher than waiting time, which in turn is valued higher than in-vehicle travel time.
- The probability of choosing Transmilenio is more sensible to the fare and the walking time to stations, while the demand for the traditional system is more sensible to in-vehicle travel time.
- There is a modal preference towards Transmilenio.
- Prepayment of Transmilenio implies a commitment to this mode playing a big role in the mode selection process.
- Transmilenio competes with the existing service on the basis of level of service rather than on the basis of price.

These results show that a bi-modal transport network has been created; in this case BRT is not considered just a faster bus because in addition to lower travel time other factors seem to be playing a relevant role. This argument is elucidated by the following finding, if one takes the travel time exhibited by the traditional system as the baseline, Transmilenio has reduced the travel time for many, but not for all transit users. For potential transit riders starting their trip in the vicinity of the trunk corridors, Transmilenio on average, offers a total travel time difference of 11.6 minutes per trip. Yet, for those living further apart and accessing the trunk corridors via feeder routes, the difference is favorable to the traditional system by 2 minutes. Notwithstanding this difference, Transmilenio still captures a larger share of the market demonstrating that other attributes (i.e., safety, reliability, and security) seem to play a role in the modal decision. The lower value of time for Transmilenio is consequent with this finding.

6.3 To what extent has Transmilenio modified travel behavior?

Notwithstanding the aforementioned benefits, this study has not produce conclusive evidence to prove that Transmilenio has modified many of the causal relationships governing travel behavior. Some of the anticipated changes can only be fully apprehended in the long term and two years of operation may be too short time to conduct such a study. For instance possible changes in auto ownership as a function of wealth or the influence that distance from the city center could have on travel time as land use is transformed by the new BRT corridors can only be evaluated later in time. Nevertheless, many transit users are undoubtedly experiencing a better service which implies that:

- For Transmilenio riders, the daily travel time gap with auto users has been reduced, for the remaining customers of the existing public transportation system such gains have not occurred. Concerning the disparity in the daily trip rates there is no evidence to show that there has been a change.
- Transmilenio rider's valuation of travel time is now reduced and therefore one can say that besides the reduction in quantity of travel time, the new system has improved the perception of the quality of the time being spent traveling.
- If one accepts the idea of a fixed daily travel time budget, a service that offers reduced travel time (i.e., Transmilenio) expands the range of action of a person. Thus more jobs, education opportunities, and amenities are accessible.
- Under the assumption that the situation for auto users has not improved, one can indicate that as the level of service in transit raises, which has been confirmed, the difference between the utility of auto and transit shrinks and the probability of using the latter rather than the former increases. Anecdotic evidence seems to support that view, yet to this point there is no way to quantify the magnitude of the change. [18]

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[18] The study of utilities per se only provide ranking information, therefore it is not possible to say by how much one utility is greater than the other, instead the study of the choice probabilities associated with them are indicative of changes.

The major impact on travel behavior of the introduction of a new "better" public transport system is the reduction in the value that is assigned to travel time. Controlling for income level and opportunity cost of the trip, as a better transportation mode is introduced the traveling time is less distasteful and therefore the valuation of time (as willingness to pay for time savings) is reduced.

A direct comparison of the changes emerges as a research opportunity. One alternative is to develop a longitudinal study collecting data through an activity diary exercise completed by a group of people living in the vicinity of one of the corridors planned for BRT development in the future. The first wave of data collection would be captured before the BRT starts operation and a second wave a couple of months after its introduction. This exercise could reveal more clearly the effects of the new system; of special interest would be modal shifts from auto to transit, changes in travel time accounting for day-to-day variation, changes in the value of time and modification of the daily trip rate. All these linked to possible changes in socioeconomic characteristics as well as to the modifications in the supply of public transportation.

6.4 Are benefits and changes in travel behavior uniformly distributed among all public transportation users?

The interest in this question is to found out how the impacts on travel behavior and particularly the travel time benefits differ as a function of socioeconomic characteristics or traveling conditions. It is clear that two classes of transit users have appeared, the first one comprised by those having access to the new BRT and the second one by those without it. The first group is enjoying better travel conditions while the second is still, by large, subject to the previous conditions. Within the Transmilenio users group there are also differences, in particular in regards to distance from the CBD and level of wealth:

- As mentioned earlier, distance from CBD plays an important role in the way the Transmilenio benefits are accrued by the population. For those accessing the system via feeder lines the difference in travel time between the two public transportation system is smaller than for those having direct access. As the potential passenger starts the trip further away from the city center, Transmilenio becomes less competitive in terms of travel time.

- When comparing the BRT benefits and indicators of travel behavior across income groups for users with direct access to the trunk corridors, Transmilenio appears to have a greater impact on the lower income groups. The potential savings in travel time are greater for this group; in fact Transmilenio's market share is higher in this segment. BRT offers a shorter travel time for those in the lower income group while the traditional offers a longer travel time. Hence, the layout and implementation of the BRT do not seem to follow a preference towards favoring the groups with the higher level of wealth.
- When examining the value of time, this study found that it is always lower for Transmilenio irrespective of the level of wealth. Despite the lack of significance of some of the travel behavior indicators, the difference in the valuation of time (a proxy for the distastefulness of traveling) between the two modes across income groups is greater for the traditional than for the BRT. Therefore, Transmilenio has shrunk the differences in the perception of transit between the different wealth groups of the population.

Thus far, the first three questions have looked at how Transmilenio has changed the travel behavior of transit users vis-à-vis the traditional competing mode. Emerging from the main findings one can propose policy recommendations in regards to the planning and operations of both systems.

- Improvement of the walking environment is key to reduce the perceived burden of public transportation irrespective of mode. The need is more severe in regards to the traditional system. Transmilenio treatment of areas surrounding the stations and the access to the waiting platform, along with its integration to the network of sidewalks and bike paths is a cause of the lower values of walking time for BRT. Recent attempts by the city to recuperate pedestrian spaces are instrumental in improving public transport competitiveness against the private vehicle.

- The same logic applies to the value of waiting time, consistently this time is valued less in Transmilenio; waiting inside a shelter is definitely better than doing it in the curbside. The consequences apply for the traditional system where bus shelters are rarely used despite their existence and recent upgrade, and for feeder lines where they need to be improved.
- The traditional system needs to be transformed in order to reduce the disparities with the BRT users. Whether it should be replaced by the BRT or migrate towards an intermediate point is a matter that will be discussed in the next section. Nonetheless, there is evidence that improvements are needed and the passengers are willing to pay for them; Transmilenio itself is a proof that this can occur.
- Besides offering lower travel time, BRT implies additional attributes that are valued by the customers. Travel time in a way is guaranteed by the exclusive use of lanes and other traffic interventions like signal preemption, however the other attributes are associated with the management of the supply in terms of maintaining cleanliness in stations and vehicles, keeping the safety and security levels, and maintaining acceptable levels of passenger loads in the buses by improving the operational management of the system.
- The differences in the valuation of the mode attributes (i.e., bimodal network) must be taken into account when forecasting demand on new trunk corridors, extensions of existing ones, or operational changes.

6.5 What are the challenges and opportunities that the new institutional arrangement will face given the changes in travel behavior?

The entry of Transmilenio in the market for public transport passengers has created a bi-modal network where the superior, yet not the market dominant mode, receives most of the attention from the city administration. This is natural since Transmilenio is seen as the spearhead of a bigger transformation where the government can play a more effective role; furthermore, the city shares part of the system's revenue. On the other hand, the inferior yet dominant mode, captures less attention and still there are not significant signs of changes.

Thus, the biggest challenge for the city is how to balance the policies between the two systems. Underlying this concern are two concrete aspects:

a. The growth of the BRT network
b. The public transportation fare

Three actors are seen as the determinants of the development of these two aspects, namely:

a. The government (Transmilenio S.A. and the Secretariat of Transit and Transport)
b. The private providers
c. The riders

Following, the two aspects that constitute the challenges for the city will be analyzed from the perspective of each of the three actors. Rather than providing conclusive answers this section proposes questions and raises policy concerns about the future development of public transportation in the city.

6.5.1 The Growth of the BRT network

The introduction of Transmilenio was justified by large, through the necessity to reduce travel time for public transport users. Its implementation has created a bimodal network where, on the one hand, those that have access to the BRT had indeed reduce their travel time and consequently their valuation of further time savings have diminished. On the other hand, those without access, which still comprise approximately 90% of the daily demand for transit, are still subject to a poor level of service. This situation implies that extensions of the BRT are desirable; however as the network extends, more people will benefit from improvements and therefore the willingness to pay for further time savings, measured for the whole population, will drop. Therefore investments in BRT exhibiting diminishing returns of scale must have an equilibrium point where further extensions will not produce the required improvements and demand to justify the investments.

The consequent question is whether the BRT, and its feeder system should fully replace the traditional public transportation mode and carry on with the potential economic losses or instead, should the traditional system be enhanced in such a way that the disparities between the two groups are reduced from both ends.

From the perspective of the city administration, two agencies are involved; on the one hand, Transmilenio S.A. has direct responsibility over the planning and operation of the Bus Rapid Network (i.e., trunk and feeder services); on the other hand the Secretariat of Transit and Transport (STT) has the responsibility of regulating and licensing the operation of the traditional public transportation mode. Transmilenio has already planned a network for the year 2016 that converts virtually all the main roads of the city into BRT trunk corridors. The completion of this plan will depend on the performance of each incremental corridor and in the possibilities of implementing the next one, which are constrained by the typically limited financial resources and the anticipated benefits which exhibit diminishing returns of investments. One barrier for the implementation of a new corridor is the relocation or cancellation of the existing routes authorized by the STT, this is a point of conflict between the two agencies. If the plan works according to schedule, thirteen years from now most of the city corridors will be served by high quality service, however this is a lengthy process and the city still needs to improve service for those corridors by licensing routes than later will be cancelled. The conflicting interest between the long term planning (i.e., Transmilenio) and the short term planning (i.e., STT) needs to be resolved for the city to take advantage of the benefits of Transmilenio.

The second actor, the private providers are involved in the delivery of transportation services in both modes. Most of the firms that take part in the operation of Transmilenio as providers of trunk or feeder routes, are still operating as individual transport companies in the competing mode. However, entry into the BRT operations is somehow limited to the strongest companies because of the high initial capital investments required; thus one can think that if the BRT network increases, the concentration of the industry will grow leaving many small operators out of business. The response within the transit industry to the extension of the system is likely to be mixed and troublesome because at some point some firms will benefit more from the extensions of the system while others will do so from its limitation.

Thirdly, the way users perceive the two modes and react to changes in the supply of public transportation is likely to shape the development of the network. Regardless of the economic results of a new corridor, some sectors of the population that may not be served by the BRT would demand its service therefore impacting the decisions of the administration. Those that are left out of the area of influence of the trunk corridor services will be part of the group exhibiting the higher disparities to the private automobile and to the BRT riders alike. At one point, the city administration as a whole has to reach an agreement on which corridors will be developed for BRT and which will not, negotiate with the providers the operation, and involve the community in the decision making process to minimize the likely negative responses from those sectors that are being unattended. In order to do this, the traditional existing service must be upgraded along with the BRT rather than being totally displaced from the market.

Lastly, an additional barrier to the extension of the network is the capacity constraints of the BRT technology, in particular in the core of the system in the CBD. A detailed analysis of this situation is out of the scope of this study but it is definitely a constraint and an opportunity for further research.

6.5.2 The public transportation fare

The second aspect where the city is likely to encounter challenges is in the issue of fare setting. First, it is important to clarify that the two systems do not have fare integration. Currently the fare is defined by the Secretariat of Transit and Transport for both modes, however for Transmilenio is estimated regularly according to the contract conditions while for the traditional mode the situation is less clear and typically follows a negotiation process between the administration and the transport providers. This study has found that the demand for Transmilenio is more elastic to fare changes than the demand for the traditional system. A 1% increase in the Transmilenio fare would produce a drop of 0.67% in the probability of choosing this mode and an increase of 1.54% in the probability of choosing the competing mode. On the other hand, an increase of 1% in the fare of the traditional system would produce a 0.40% drop in the probability of choosing it and an increase of 0.17% in the probability of selecting Transmilenio. Thus, as the fare gap increases, Transmilenio demand is likely to be more affected than the demand for the traditional system.

From the city administration perspective, again there are conflicting interests. One must start the argument by acknowledging that the fare for both modes is likely to increase more than once in a yearly basis as it has been happening during the last two years. The fare for Transmilenilo, which is part of the contractual agreements with the operators, is likely to be the driver of the fare for the whole system. If the Transmilenio fare increases much more than the one for the traditional system, demand for the first one is likely to fall in favor of the former. Therefore, at least from the purely financial standpoint, there is an interest from Transmilenio to raise the fare of the competing mode irrespective of the level of service of the competing mode. Transmilenio is competing on the basis of the level of service and not on the basis of price. From this perspective the riders of the traditional mode would be affected negatively since a higher fare does not guarantee a better service.

From the perspective of the transportation providers, an increase in the fare will always be received well. Assuming that the Transmilenio fare is set following a strict inventory and accounting of production costs according to the contracts signed with the administration, the fare increase will go into maintaining the existing level of service. On the other hand there is no contractual agreement or an established protocol to monitor the investments that the operators in the traditional mode make in their vehicles; stressing the aforementioned point, they compete based on lower prices and therefore an overall improvement of the service is not likely to happen.

Finally, from the perspective of the riders, an increase of the fare is likely to be badly received. Even more when there are no productivity gains reflected in a better level of service, as typically happened for the last 50 years. Many people in Bogotá paid the increase fare of Transmilenio showing that there is some room for improvement of the service at a higher cost; what is more difficult to accept now that there is a better option is that the fare increases and no improvements to the service are implemented.

In regards to this issue, one single integrated fare emerges as an additional option. However, for this situation to occur the level of service of the traditional system must be upgraded in such a way that it is similar to BRT. It is very unlikely that Transmilenio would accept fare integration without this precondition because the lack of it will mean that the higher service is subsidizing the poorer service. Under the current institutional arrangements this cross subsidy scheme does not seem feasible.

6.6 General conclusions

For cities in developing countries where the existing mode of public transportation offers a valuable but rather poor service, the introduction of a better transportation system is an attractive and certainly needed investment. Bus Rapid Transit technologies are a feasible option because of its low cost and relative ease of implementation. However, due to the very high demands for transit, the size of the cities, and the presence of n active private industry that delivers the service, its introduction will change travel behavior and is likely to produce the following situations:

- Savings in travel time are likely to occur, benefiting a group of the population.
- Improvements of the pedestrian access to the new mode is instrumental in maximizing the benefits of the new system.
- The value of time in the superior mode will be lower than in the inferior one, that is, the willingness to pay for further improvements in the new mode is also lower. Therefore investments exhibit diminishing returns.
- A bi-modal public transportation network could be created since the superior mode is likely to be perceived in a different way than the existing one.
- The superior mode will compete on the basis of level of service while the existing one will be competitive on the basis of price or where it holds monopolistic position.
- The coverage of the superior mode will be determined by large, by the quality of the inferior quality service.
- The fare for all public transportation modes is likely to be driven by the fare of the higher service mode.
- The introduction of a superior quality service is not guarantee that the whole city will be serviced; therefore the improvement of the existing inferior quality service is paramount.

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